

# **Towards the Improvement of Training in Foreign Languages**

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TOWARDS THE IMPROVEMENT OF TRAINING IN FOREIGN LANGUAGES

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## TOWARDS THE IMPROVEMENT OF TRAINING IN FOREIGN LANGUAGES

Almost by definition, military activity is international and multilingual. It is imperative, therefore, that some segment of military personnel have a working command of the languages of those individuals with whom they need to interact and communicate. Foreign language training programs have been developed in the military to meet this need.

It is possible to structure language training in any of a variety of ways. At one extreme is training that focuses on the abstract grammar underlying an ideal speaker's knowledge of the language. This course would be designed to promote the acquisition of formal linguistic principles that describe the structure of language. Consider, for example, the rules for pluralizing English nouns. One such rule refers to the distinctive phonetic feature of "voicing." Specifically, correct pronunciation requires that there be voicing assimilation, or an agreement in voicing, between the final consonant of the root noun and the plural morpheme. A language course could be organized around such principles, and indeed this is the standard practice in many educational settings. At the other extreme is training that focuses on the psychological principles that influence a real speaker's comprehension and production of the language. This course would be designed to promote the acquisition and use of pragmatic psycholinguistic principles. For example, earlier experiments by Healy and Levitt (1980) have shown that naive individuals do not have access to the concept of voicing, although they can easily learn a phonological rule based on voicing assimilation if it coincides with ease of pronunciation. A language course could be organized around such principles; however, at present a course based primarily on psychological, as opposed to formal linguistic, principles has not been realized. It was the ultimate goal of our project to identify a set of psychological principles that could provide the foundation for or, at least, augmentation of a foreign language training course.

It would be unrealistic to expect that in one limited project we would be able to address the full range of psychological principles that such a course requires. Our goal has been more modest. Nevertheless, during the three years of our project, we have investigated a wide range of potentially valuable psycholinguistic issues relevant to language training. Among the issues of greatest concern to us have been: (a) To what extent does a person adopt or adapt first-language strategies in the acquisition and use of a second language? (b) What are the best methods for efficient and durable acquisition of vocabulary items in a foreign language? (c) What role do abstract linguistic categories play in the acquisition of language skill and the day-to-day use of language for the purpose of communication? (d) What are the functional units of any language and how do they differ for the native and nonnative speaker? (e) How do knowledge of the language and utterance complexity interact to determine message comprehensibility for a listener?

Overriding these questions is a fundamental interest in designing optimal training programs. We define optimality in terms of three characteristics: (a) minimize the time to reach a criterion level of performance, (b) ensure the long-term retention of the acquired knowledge and skills that underlie performance, and (c) provide for maximal transfer of what has been learned from the training context to other environments, especially those crucial to military activity. Our own earlier research (see Healy & Bourne, 1995, for a summary) has underlined the importance of all three of these criteria. For example, we have discovered that training that minimizes acquisition time may, in fact, be detrimental to long-term retention. Likewise, in other studies, we have found that training that maximizes long-term retention may severely limit the transferability of that material. It is, thus, vitally important that all three characteristics of on-the-job performance be considered to establish the validity of an instructional program.

Our project addressed both first- and second-language learning and use. In some studies, we employed subjects of varying degrees of fluency in the second language, expecting that the degree of fluency would have an important impact on the relevant psychological processes. However, in other studies, we focused exclusively on performance in the first language, because we were convinced that understanding the psychological processes underlying first-language use would yield valuable insights into the optimal methods for training in any other language.

We began this project on August 2, 1993, and over the following three years we made considerable progress on a number of issues. Here, we will review some of our most important findings.

#### Transfer of Strategies from First to Second Language

The first issue we will discuss concerns first-language strategies in second-language use. In earlier work (Tao & Healy, in press), we tested two related hypotheses concerning the connection between language and cognition from a linguistic perspective. The first hypothesis is that the structure of a particular language elicits unique strategies which speakers utilize to process discourse information. We refer to this as the "language-specific strategies hypothesis." The second, related hypothesis is that the strategies formed as a result of the native language structure are likely to influence speakers when they process discourse information in a non-native language. We call this the "strategies transfer hypothesis." Our experiments tested these hypotheses specifically on the different cognitive strategies that speakers of English and Chinese use to track references in a discourse.

One of the major differences between English and Chinese is that Chinese relies much more on the use of zero anaphora, which is an empty grammatical slot in a sentence that in English is usually filled with a noun phrase or a pronoun. For example, consider the English sentence, "Hillary Clinton went to Boulder, and the first lady spoke to CU students." "The first lady" is a noun phrase that refers to Hillary Clinton. This noun phrase could be replaced by the pronoun "she," as in the sentence "Hillary Clinton went to Boulder, and she spoke to CU students." Alternatively, it could be replaced by an empty slot, which is known as "zero anaphora," as in the sentence "Hillary Clinton went to Boulder and spoke to CU students." Although, as is clear from this example, English does make some use of zero anaphora, this device is much more commonly used in Chinese.

Earlier, we conducted three experiments which tested native English and native Chinese speakers on their ability to tackle zero anaphora in English passages (Tao & Healy, in press). We employed three different types of passages. In the first type (full form), no elements were missing. In the second type (missing noun phrase), there were missing nominals corresponding to zero anaphora in Chinese. In the third type (missing modifier), there were missing modifiers in noun phrases which created ambiguous anaphoric referents.

Subjects were given discourse passages with missing nominals, but there were no blank spaces or other indication that any words were missing. The subjects were instructed to read each passage once, and then to give a comprehensibility rating to the passage.

The results of the three experiments revealed that, even though the passages were in English, the native Chinese speakers gave significantly higher comprehension ratings to the missing noun phrase and missing modifier passages than did the English subjects. In contrast, there was no significant difference between the two groups in their comprehension ratings for the full form passage.

In two of the experiments, subjects were also given a fill-in-the-blank test, in which missing elements were indicated in the passages by blank spaces, and subjects were asked to fill in the missing words along with a

confidence rating for each choice. On this task we found no disadvantage for the native English speakers, suggesting that they have the ability to track the missing referents although they may not invoke that ability when there is no explicit indication of a missing word.

The three experiments provided strong evidence supporting both the language-specific strategies hypothesis and the strategies transfer hypothesis. The experiments demonstrated that the native English speakers, although capable of tracking missing referents in a discourse, had more difficulty processing discourse information than did the native Chinese speakers when there were many instances of zero anaphora in the discourse.

In two more recently completed experiments (Tao & Healy, in preparation), we examined two new subject groups. In Experiment 1, we compared native English speakers and native Chinese speakers to native speakers of Dutch, a language close to English that also has infrequent zero anaphora. In Experiment 2, we compared native English speakers to native speakers of Japanese, a language that does have frequent zero anaphora, as does Chinese. We expected to find the native Dutch speakers' performance similar to that of the native English speakers and the native Japanese speakers' performance similar to that of the native Chinese speakers. Both experiments yielded evidence supporting these predictions.

Specifically, in Experiment 1, subjects were given the comprehension rating task with both missing noun phrase and full form passages. The results are summarized in Figure 1. The native Dutch speakers showed a pattern of results much closer to that of the native English speakers than to that of the native Chinese speakers. Note in particular, that the Chinese subjects gave somewhat lower comprehension ratings than did the Dutch subjects to the full passage, but the Chinese subjects gave much higher comprehension ratings than did the Dutch subjects to the missing noun phrase passages.

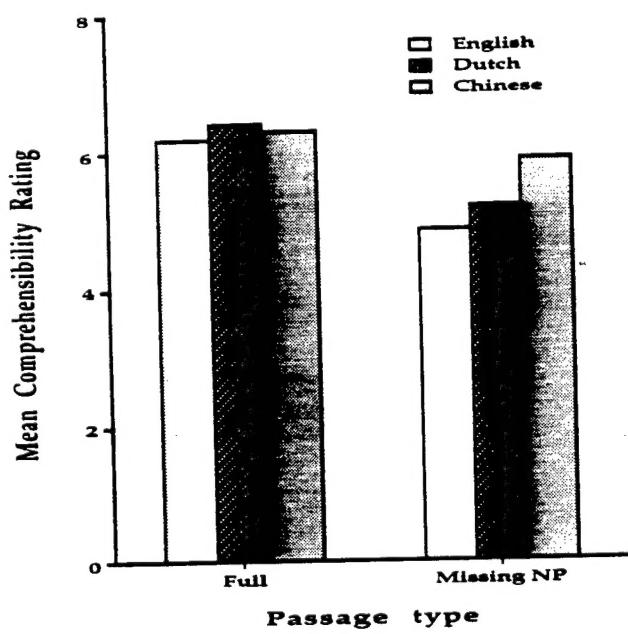


Figure 1. Mean comprehensibility rating for native English speakers, native Dutch speakers, and native Chinese speakers as a function of passage type.

In Experiment 2, subjects were given both the comprehension rating task and the fill-in-the-blank test with both missing noun phrase and missing modifier passages. The results are summarized in Figure 2. For both passages, the native Japanese speakers gave somewhat higher ratings than did the native English speakers on the comprehension task but somewhat lower ratings on the fill-in-the-blank test.

In two new experiments (Tao & Healy, 1996), we tested native English and native Chinese speakers on their ability to comprehend English passages with zero anaphora, with comprehension measured using an objective test rather than the subjective ratings used in the earlier studies. We gave subjects four English passages, all taken from a standardized reading test. For each subject, two of the passages were written in full form, as they appeared on the standardized test, whereas the other two were written with noun phrases deleted where Chinese would use zero anaphora. Consider a section from a sample passage in each of the two forms. In the full form, subjects read, "I once had a brother who committed a great crime, for which he was hanged." For the zero anaphora form, the pronoun "he" was deleted, so that subjects read instead, "I once had a brother who committed a great crime, for which was hanged." Note that we added nothing to the zero anaphora passage to indicate the location of the missing noun phrases.

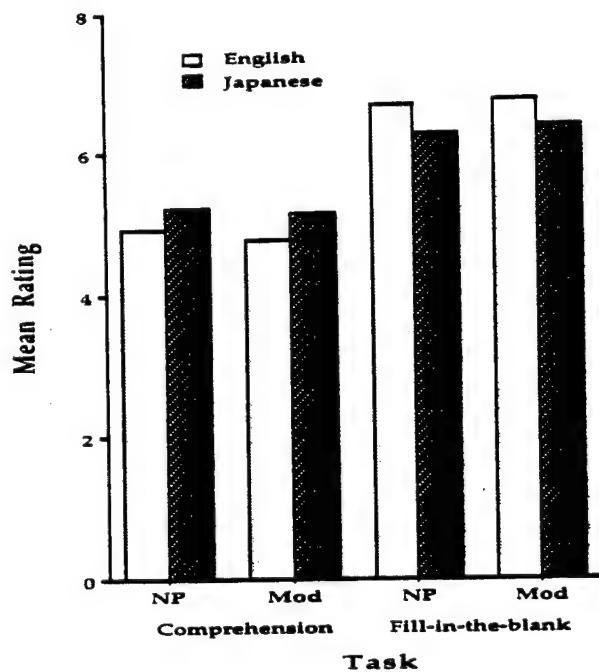


Figure 2. Mean rating on the comprehension task and fill-in-the-blank task with both missing noun phrase (NP) and missing modifier (Mod) passages for native English speakers and native Japanese speakers.

Subjects read each passage once in a self-paced manner. Each passage was followed by a set of three general and three specific multiple-choice comprehension questions. A sample specific question corresponding to the passage segment is "The nobleman [who was the protagonist of the story] claimed that his brother: (a) committed a crime, (b) had an accident, (c) was sick, or (d) none of the other three is true."

Our results are summarized in Figure 3. As expected, subjects overall made more errors on the zero anaphora passages than on the full form passages. In addition, importantly, the interaction of subject group and passage type is striking. It is most interesting to note that the native Chinese speakers actually made fewer errors than did the native English speakers on the objective comprehension test of English passages with missing noun phrases, although they made somewhat more errors on the full passages with no missing words..

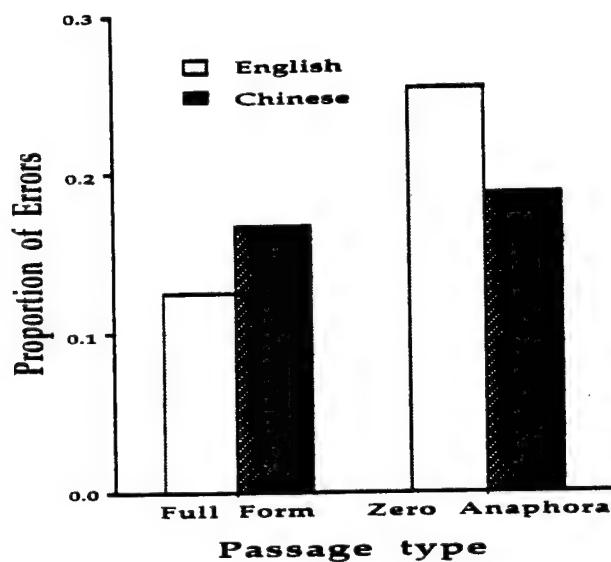


Figure 3. Proportion of comprehension errors for native English speakers and native Chinese speakers as a function of passage type.

Zero anaphora in Chinese follows the same discourse pragmatic rules as does the use of pronouns in English. For example, it would not be appropriate to use either zero anaphora in Chinese or a pronoun in English to introduce a noun referent that had never been mentioned before in the discourse. We conducted a second experiment in which we compared English passages containing zero anaphora (zero anaphora form) to those containing missing noun phrases that would not be appropriate as zero anaphora in Chinese because of violations of the discourse pragmatic rules (violation form). The zero anaphora form for the sample passage is the same as used previously; subjects read "I once had a brother who committed a great crime, for which was hanged." Recall that the pronoun "he" from the full form was deleted in this example. The violation form keeps the pronoun "he" from the full form but deletes instead the noun phrase "a brother." That passage reads, "I once had who committed a great crime, for which he was hanged."

The results of this experiment are summarized in Figure 4. As expected, subjects overall made more errors with the violation form than with the zero anaphora form. In addition, importantly, once again we have a striking cross-over interaction, with the native Chinese speakers showing somewhat more errors than the native English speakers on the passages in the violation form but considerably fewer errors on the passages in the zero anaphora form.

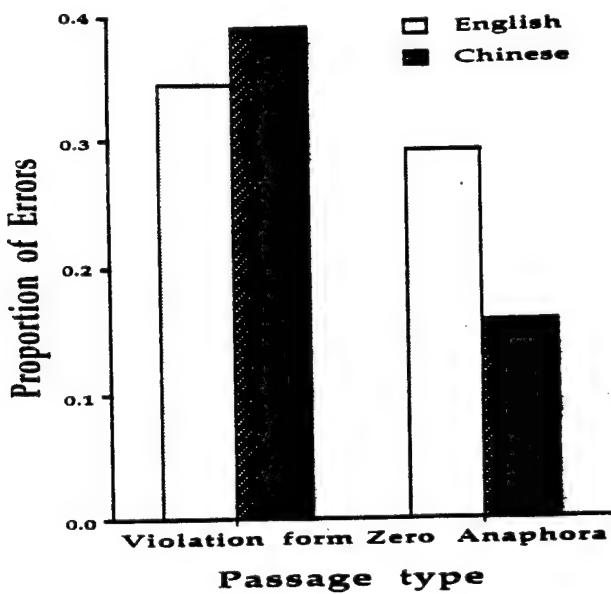


Figure 4. Proportion of comprehension errors for native English speakers and native Chinese speakers as a function of passage type.

Together, the two new experiments provide strong support for both our language-specific strategies and our strategies transfer hypotheses. In particular, the discourse strategy used by the native Chinese speakers to comprehend zero anaphora in Chinese was applied by these subjects to the comprehension of English passages with zero anaphora, so that the native Chinese speakers showed superior comprehension of these passages than did the native English speakers. The particular discourse strategy employed by the native Chinese speakers needs to be specified and tested, but Tao (1996) has outlined a reasonable candidate which she refers to as "emergent reference." By this account, Chinese speakers are particularly sensitive to information and cues from the verb and the sentence context which are combined to constrain the identity of the missing noun referent. A full understanding of this strategy could lead to improvements in language training, especially for languages like Chinese and Japanese with abundant zero anaphora.

#### Vocabulary Acquisition and Retention

##### Mediational Processes

The second issue we will discuss concerns vocabulary acquisition and retention. An important component of improving foreign language acquisition is improving the efficiency and effectiveness of acquiring new vocabulary. One approach to achieving this goal is to make use of existing knowledge. For example, in acquiring new vocabulary, various mediation techniques may be used. One such technique is the Keyword Method in which an unfamiliar foreign word is first related to a similar-sounding native-language keyword which in turn is related to the English equivalent using an interactive image. For example, the Spanish word cabra, meaning goat, can be learned by first noting the similarity in sound of cabra to the English keyword cab and then generating an interactive image of a goat driving a cab.

Although, there is general agreement that the use of mediators is related to initial ease of learning and retention, the functional role of mediators in encoding and retrieval processes is unclear. For example, it is unclear whether mediators serve simply as a context for forming new associations between familiar and unfamiliar items or whether the mediators become a functional part of the actual memory representation relating the two items. The problem is that given the covert nature of mediation processes, earlier approaches to studying mediation lacked sufficient power to address such issues. However, without a clear understanding of the functional role of mediators in memory processes, it is difficult to know precisely what makes a good mediator or how to improve mediational techniques.

We have developed a coherent set of methodologies for studying mediational processes in memory. In our previous experiments (Crutcher, 1990, 1992; Crutcher & Ericsson, 1992), we showed that when keyword mediators are provided to subjects to learn foreign-English vocabulary pairs, the keywords play an important role in subsequent memory retrieval processes, serving as intermediate retrieval cues to recover the English translation corresponding to the foreign word. With practice, this retrieval process changes, speeding up dramatically, with subjects no longer reporting keyword mediators in retrieving the translations. Nevertheless, it appears that these mediators may continue to be involved covertly in the retrieval process.

In a recent study (Crutcher, in preparation), we used some of the methodologies employed in our previous experiments to compare subjects who learned a set of foreign vocabulary with the keyword method to a free-strategy control group who simply learned the pairs any way that they could. One goal of the study was to determine whether providing subjects with mediators would produce faster acquisition and better retention. A second goal was to determine whether the control subjects were using any mediation techniques of their own in learning the vocabulary pairs.

Specifically, subjects learned a set of Spanish-English vocabulary items presented individually using a self-paced procedure. Following acquisition was a cued recall task in which subjects saw the Spanish word and responded by saying the English equivalent into a voice key that recorded the response latency. On incorrect responses, subjects received corrective feedback, and each missed item was later re-presented until it was responded to correctly. After this dropout phase, the vocabulary pairs were tested, again using the cued recall procedure but without feedback. Verbal reports were collected throughout the experiment. During acquisition, subjects thought aloud as they studied each item, and during testing they provided retrospective verbal reports after each response, reporting whatever they remembered thinking for that trial.

An analysis of the total number of trials to criterion revealed that the free-strategy subjects required more trials ( $M = 77$ ) than did the keyword subjects ( $M = 51$ ). Further, on the test, the proportion of correctly recalled vocabulary pairs was reliably greater for the keyword group (.97) than for the free-strategy control subjects (.80).

Thus, keyword subjects learned the vocabulary pairs faster than did the free-strategy group. In addition, use of keyword mediators led to better retention of the vocabulary pairs. In view of the three characteristics of optimal instructional programs discussed earlier, these results suggest the potential utility of mediational techniques such as the keyword method in designing a language instruction program. However, an important follow-up to the present study would be to assess whether the retention advantage observed at a short delay interval would also remain after a longer delay.

A second goal of the current study was to obtain information concerning the free-strategy control subjects. Towards that end, we coded the think-aloud verbal-report data collected while subjects were studying the foreign vocabulary items in this experiment. We found that on every trial, the

keyword-instructed subjects reported a keyword mediator. The no-strategy subjects also reported using keyword mediators on a substantial proportion (.38) of the learning trials.

This experiment suggests the interesting possibility that keyword strategies are in fact utilized quite commonly by at least some individuals. In addition, a number of our earlier studies suggest that when vocabulary is acquired using such mediators, these mediators continue to influence memory retrieval processes. Together, these results point to the importance of clearly understanding what makes an effective mediator. With respect to keyword mediators, there appear to be two factors that determine their effectiveness: First, how readily the foreign word can be related to the keyword (for example, cabra to cab), and second, how easily the keyword can be linked to the English translation (for example, cab to goat).

To study the first factor and to determine objectively the relative "accessibility" of a keyword with respect to the foreign word, we asked an independent group of subjects to generate as many keywords as possible for a set of Spanish words. Keywords generated with high frequency across all subjects were classified as "good"; those generated with low frequency were classified as "poor." For each Spanish word, we then selected one good keyword and one poor one, with the two keywords equated for concreteness and imageability.

We used these keywords in an experiment in which subjects learned the English translation for the set of Spanish words, using the good keywords for half of them and the poor keywords for the other half. After learning with corrective feedback, the vocabulary pairs were tested using a cued recall procedure in which the Spanish word was presented and subjects responded with the English translation.

Recall accuracy was higher for the pairs learned using the good keywords (.94) than for those learned using the poor keywords (.78). In addition, for the correctly retrieved items, pairs learned with the good keywords were retrieved faster ( $M = 2095$  ms) than those learned with the poor keywords ( $M = 2501$  ms). Both results supported the hypothesis that the accessibility of the keyword from the foreign word is an important factor in determining the effectiveness of keyword mediation.

To summarize, in our first experiment we found that subjects sometimes spontaneously employ keyword mediators in trying to learn unfamiliar foreign words, which may be why instructing subjects to use keyword strategies is often successful: The strategy is one that appears to be used to some degree by subjects but perhaps not as effectively as possible. Specifically, subjects may not be completely successful in identifying ideal keyword mediators. The second experiment speaks to the issue of what makes an effective keyword mediator by demonstrating that it is due at least in part to how readily the keyword can be accessed from the foreign word.

Now that we have been able to establish that the quality of a keyword has a short-term effect on vocabulary acquisition, it is important to determine whether it has a long-term effect as well. Do better keyword mediators improve only initial acquisition or do they contribute to the durability of retention for the vocabulary pairs? In our future work we plan to address this fundamental issue.

As mentioned previously, in our earlier research on mediational processes in foreign vocabulary acquisition (e.g., Crutcher, 1992), we found that in early learning trials, keyword mediators serve as retrieval cues to recover the English translation corresponding to the foreign word. With practice, this retrieval process changes, dramatically speeding up, with subjects no longer reporting the need for keyword mediators to retrieve the translations of the foreign words. Nevertheless, we have found that even after extended practice the keyword mediators continue to influence memory retrieval despite subjects' lack of awareness of the mediators in the process.

This influence is evidenced by significant increases in Spanish-English retrieval latencies when new associations to the old keyword mediators are learned. For example, after learning cabra-goat using the keyword mediator cab, a subject practices retrieving cabra-goat for 80 blocks, after which the keyword mediator cab and the interactive image of a goat driving a cab are no longer reported. Nevertheless, when a new response to cab is learned (such as cab-flower) there is a significant slowing of the retrieval latency for the cabra-goat pair relative to a control condition in which a new response is not learned. Our explanation for this effect is that the retrieval of the translation is still tied to accessing the keyword at some, probably implicit level. Learning a new keyword association thus produces interference in accessing the English translation. The key question is, what aspect of the keyword mediator in fact produces the interference. Our current explanation relies on conceptual or semantic interference, in which the concept cab spreads activation to the related concepts goat and flower. Naturally there are other possible explanations for this interference effect that need to be ruled out. Recently, we completed two experiments that further test the conceptual interference account (Crutcher, in preparation).

The first experiment tested the conceptual interference hypothesis as well as an alternative account that argues that the mediating semantic structure is no longer involved in retrieval. Possibly then, the source of the interference effect is the physical similarity of the keyword cue in the paired associate task to the Spanish word cue in the Spanish-English retrieval task. In other words, after sufficient practice, a direct connection is established between cabra and goat with the goat driving the cab semantic structure no longer playing any role. The acquisition of cab-flower produces interference in trying to retrieve goat from cabra not because of a shared link to the concept cab but because of the physical similarity of the retrieval cues cab and cabra. If this is the case, then learning a word pair using a new keyword physically similar to but conceptually distinct from the original keyword might be expected to produce interference just as the original keyword did. For example, acquisition of and extended practice with the pair cabra-goat would be followed by acquisition of the pair cob-flower in which the word cob is physically similar to the original keyword cab (and therefore to the Spanish word cabra) but semantically distinct.

In this experiment, subjects learned Spanish-English pairs followed by 80 blocks of practice to promote change from mediated to direct retrieval of the vocabulary items. This practice was followed by testing and then for some of the Spanish-English pairs our original interference condition and for other pairs our new physical interference condition. As in the previous studies, other vocabulary pairs served as controls with no new response acquired to a keyword. Our results supported the conceptual interference account, because we found longer retrieval latencies for the original interference condition ( $M = 1370$  ms) relative to both the physical interference condition ( $M = 1149$  ms) and the control condition ( $M = 1113$  ms) but no significant difference between the physical.interference and control conditions.

To provide converging evidence for this account, we also completed a preliminary experiment in which we employed keywords that were physically distinct from, but semantically related to, the original keywords. We first identified synonyms or conceptually similar but physically distinct English word pairs (e.g., coat and jacket). These synonyms served as keywords. Subjects learned a foreign word using the keyword coat and subsequently learned a new association to jacket. We retested the foreign-English vocabulary pairs following acquisition and five blocks of retrieval practice to see whether learning a new conceptual association to the mediating concept would slow retrieval of the foreign-English pair.

A new wrinkle in this study was that instead of using actual Spanish vocabulary for the foreign words, we simply made up "foreign" words (nonwords) that contained or shared a physically salient part of our keywords (for example, the "foreign" word for the keyword coat was cotamon). Thus, the pair cotamon-finger was learned using coat as the keyword and later, after a period of retrieval practice, the new pair jacket-handkerchief was learned. This new learning was then followed by retesting of the original foreign-English pair cotamon-finger. The results again supported the conceptual interference hypothesis: Retrieval of the original vocabulary pair (cotamon-finger) was indeed slowed by learning a new pair using a synonym of the original keyword (jacket-handkerchief); the retrieval latency for the conceptual interference group ( $M = 1746$  ms) was longer than that for the control group ( $M = 1544$  ms). Taken together these two experiments lend additional support to the conceptual interference hypothesis that we have proposed. Further studies in this vein are planned as tests of this account.

#### Phonemic Processes

In a second study investigating foreign language vocabulary acquisition (Feldman, 1994), we asked whether the rules of pronunciation in a student's first language influence the ease of learning vocabulary items in a second language. As subjects, we used native Japanese speakers who were all intermediate level students studying English as a Second Language (ESL) at an intensive program for college-bound foreign students. We selected 24 common English words, with the words paired so that the easy member of each pair had a pronunciation that would be familiar to a Japanese speaker and the hard member had a pronunciation that would be unfamiliar. The two members of each pair were matched in terms of syllable number and frequency in English. For example, a native Japanese speaker using Japanese rules would pronounce the easy word "increase" as [inkur'is], which sounds like the English word, but would pronounce the hard word "involve" as [imborubu], which does not sound at all like the English word.

Subjects were given two vocabulary tests on these English words. In the oral test, the words were read aloud to the subjects, and in the written test, the words were read silently by them. The order of the two tests was counterbalanced across subjects. In both tests, the subjects' task was to select the correct dictionary definition from the set provided to them on a sheet of paper. Thus, in this experiment we did not teach subjects new words, but rather tested their knowledge of common words they had been exposed to in either reading or listening.

As shown in Figure 5, we found that for both tests, subjects made many more errors on the hard-to-pronounce words than on the easy-to-pronounce words. This result is particularly interesting for the written test because nothing was spoken or heard on that test.

We also found, as shown in Figure 6, that subjects were aided on the hard words by a prior test. In particular, errors on the hard words presented orally were decreased when those words had previously been seen in written form. This effect of test order was only evident for the hard words and has important implications for teaching vocabulary. Although many foreign language programs show a preference for oral presentation of vocabulary items, sometimes relying on oral presentation exclusively, it may be very useful to combine oral with written presentation, at least when the words have a pronunciation not found in the first language of the student. More generally, the results of this study imply that it is crucial to be sensitive to the pronunciation rules of the first language when teaching foreign vocabulary items to students.

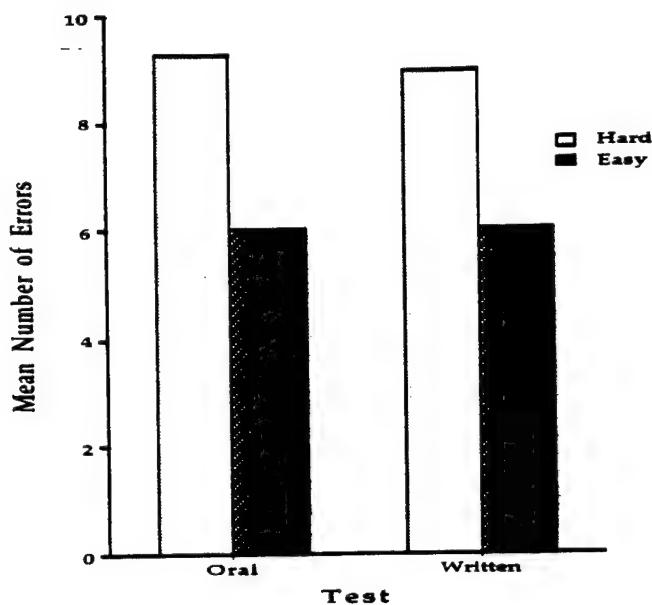


Figure 5. Mean number of errors on the oral and written vocabulary tests for native Japanese speakers on hard-to-pronounce and easy-to-pronounce words.

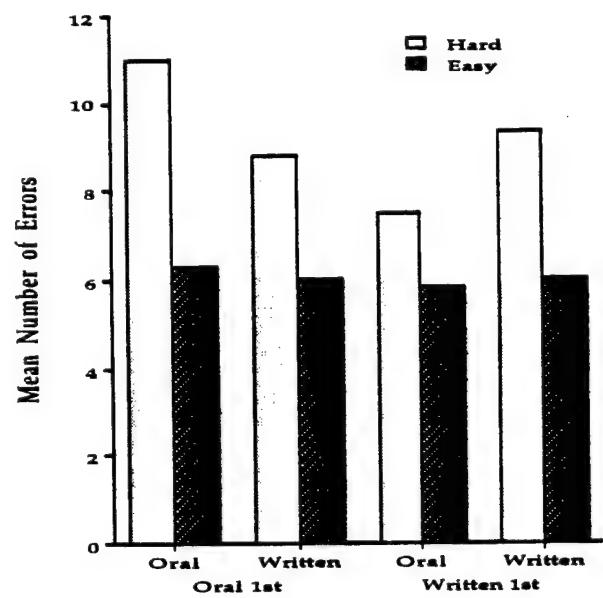


Figure 6. Mean number of errors on the oral and written vocabulary tests for native Japanese speakers on hard-to-pronounce and easy-to-pronounce words as a function of test order.

## Learning Linguistic Categories

### Abstract vs. Local Model

The third issue to be discussed concerns the learning of linguistic categories. When learning a foreign language, it is important not only to learn the necessary vocabulary, but also to learn the relevant linguistic categories that group together similar vocabulary items. One such category in English concerns the distinction between count and mass nouns. Count nouns can be defined as nouns which refer to discrete, countable objects, and mass nouns as nouns which refer to undifferentiated stuff.

The semantic distinction between count and mass nouns is correlated with various restrictions on the grammatical contexts in which those nouns typically occur. Two of the major correlations are the following: First, count nouns like "book" have both a singular and a plural form; mass nouns like "butter" have no plural form. Thus, for example, we say "books" but not "butters." Second, count nouns do not take the quantifier "much"; mass nouns do. Count nouns (in the plural) take the quantifier "many"; mass nouns do not. Continuing with the example, we say "many books" but "much butter."

To account for these correlations, conventional descriptions of English include countability as a grammatical category. Underlying this treatment is the assumption that these correlations constitute a unitary phenomenon, which can and must be accounted for by a single abstract mechanism. Hence, we refer to this treatment as the "abstract model."

Although the abstract model has been widely accepted, no satisfactory abstract analysis of the count-mass distinction has yet been devised. As noted earlier, the standard criterion is the distinction between nouns that refer to discrete, countable objects and those that refer to undifferentiated stuff. But this formulation is inapplicable to abstract nouns. There are abstract nouns which are count ("He has many good ideas"), and those which are mass ("We received too much advice"). Yet there does not appear to be any way of making their grammatical treatment as count or mass depend on properties of their referents.

Serwatka (1987) argued that the difficulty of finding an adequate abstract account of the count-mass distinction argues for the abandonment of the abstract model in favor of an alternative called the "local model." The essence of the local model is that grammatical knowledge is organized not in terms of high-level abstract generalizations or categories, but rather in terms of low-level local information or examples. In a local model, the relevant knowledge concerns allowable word combinations of individual nouns and determiners or quantifiers (e.g., speakers learn the combination much advice).

Serwatka and Healy (1989) conducted a series of concept attainment experiments which addressed the issue of choice between the abstract and the local paradigms as the basis of the grammar of the count-mass distinction. Clear support was obtained for the local paradigm.

This finding has important implications for foreign language training. It suggests that it cannot be assumed that foreign language learners have access to abstract grammatical distinctions included in a structural description of their native language. If indeed students' knowledge of their first language can be best described by the local, rather than the abstract, paradigm, it would seem best to provide local as well as abstract information to students when teaching a foreign language.

More recently, we conducted a new series of experiments to provide converging evidence for this conclusion. In this series, we examined the distinction in pronunciation of the definite article the (thee or thuh) (Healy & Sherrod, 1994).

It is well known that, in English, the indefinite article a is used preceding nouns and adjectives beginning with a consonant sound, whereas an is used preceding words beginning with a vowel sound. What is less commonly known, however, is that according to standard English dictionaries, a similar distinction pertains to the pronunciation of the definite article the. When the precedes a word that begins with a consonant sound, it is pronounced with the schwa phoneme /ə/, as thuh. When it precedes a vowel sound (as when it is given emphasis), it is pronounced with the phoneme /i/, as thee. In the present study we examined the extent to which native adult speakers of English are in command of that pronunciation distinction.

According to the conventional abstract model, the a/an and thuh/thee pronunciation distinctions together define a grammatical division of words into two categories, words coupled with a or thuh and words coupled with an or thee. Underlying this traditional view is the assumption that these grammatical divisions are governed by a single high-level, abstract construct or rule. In contrast, according to the local model of these distinctions, knowledge is particular to a single unit, such as a word or combination of words, rather than to the whole scope of a grammatical category. However, in the case of the thuh/thee pronunciation and a/an distinctions, it is not clear which is the relevant unit according to the local model. Subjects might consider a combination of an article and an adjective or a noun (such as "thee apple"), as they presumably do, for example, when learning the gender of nouns in languages like French, German, or Hebrew. Alternatively, subjects might consider a combination of an article and an initial syllable (such as "thee ap"), or a combination of an article and an initial phoneme (such as "thee a"). That is, a syllable or a phoneme, rather than an entire word, could act as a linguistic cue for the article pronunciation. In other words, the question is at what level of abstraction does the subjects' behavior become systematic or rule-like.

Healy and Sherrod (1994) tested whether the local model can explain the behavior of adult speakers of English with respect to the thuh/thee pronunciation distinction. We used a concept formation task for this purpose because it provides a way of testing for tacit knowledge or skill which subjects may put into practice even though they may be unable to describe it explicitly. Three conditions were compared in an initial experiment. In all three, subjects saw a list of 72 nouns or adjectives presented one at a time. Half of the words began with a consonant and half with a vowel. In two conditions, for each word subjects were to choose between thuh and thee. In one of these conditions, subjects received feedback, giving them the correct answer after every choice, whereas no feedback was provided in the other. The third condition was a control no-feedback condition, in which subjects had to make a choice instead between a and an.

The results are summarized in Figure 7. We found an overall error rate in the a/an condition of about 1%, indicating that subjects behaved in accordance with the abstract rule for the a/an distinction. The overall error rate in thuh/thee with feedback condition was about 6%, suggesting that feedback enabled subjects to learn the rule for the thuh/thee distinction. In contrast, the overall error rate in the thuh/thee without feedback condition was about 25%, which is well below the chance level of 50% but high enough to preclude rule usage.

We also found that subjects made more errors overall on words beginning with a vowel (where they are supposed to say "thee") than on words beginning with a consonant, especially in the thuh/thee without feedback condition. This effect of initial sound category may be due in part to the fact that the thuh pronunciation is considered acceptable preceding a vowel in some dialects. However, the high error rate in the thuh/thee without feedback condition cannot be simply attributed to a mixture of subjects who

consistently used thuh before a vowel and those who consistently used thee before a vowel because none of the subjects in that condition showed perfectly consistent selections for vowels.

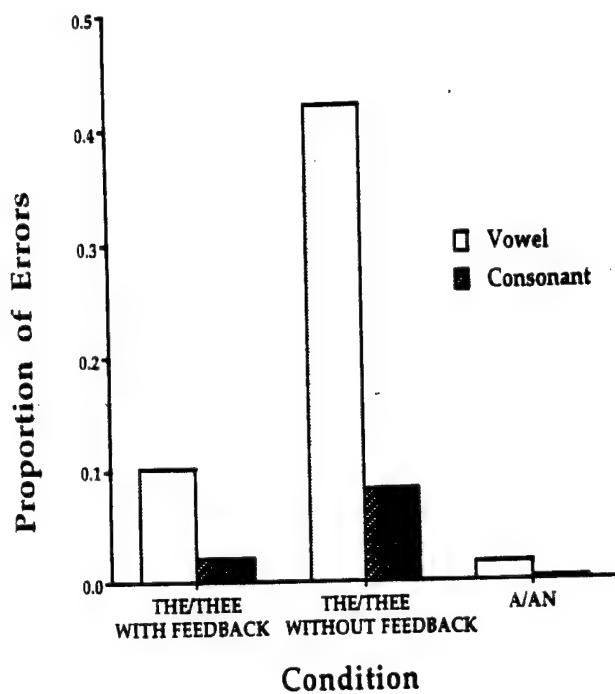


Figure 7. Proportion of errors on words beginning with a vowel and on words beginning with a consonant as a function of condition.

If a local model were operating rather than an abstract one and the relevant cues considered by subjects consist of words, then subjects should perform better on high-frequency words than on low-frequency words because high-frequency words are more familiar, thereby providing subjects with more opportunity to encounter them and to reinforce their correct usage. Finding an effect of word frequency would, thus, support the version of the local model in which subjects attend to word combinations. A local model would still be consistent with the present findings, however, if the relevant cues, instead of whole words, are word initial letters, phonemes, or syllables.

The purpose of a second experiment was to shed some light on the nature of the cues subjects were using. There were two conditions in this experiment--a/an and thuh/thee. The procedure was like that in the conditions without feedback of our initial experiment. A new list of nonspecial words was compiled, including some beginning with a vowel and some beginning with a consonant in each of two categories--high-frequency words and low-frequency words. In addition, there was a set of special words from the following four categories:

- 1) Words beginning with a vowel letter, but a consonant sound (for example, "one").
- 2) Words beginning with a consonant letter but a vowel sound (for example, "honor"). All of these words began with the silent letter h.
- 3) Words beginning with the letter h and phoneme /h/ for which the first syllable is unstressed (as in, "hotel") or weakly stressed (as in, "hypothalamic").

4) Words beginning with the letter h and phoneme /h/ for which the first syllable is stressed (for example, "hundred").

The results for the nonspecial words are summarized in Figure 8. Subjects made more errors on thuh/thee than on a/an. Further, they made more errors on words beginning with a vowel than on those beginning with a consonant, especially for the thuh/thee condition. These results support the similar findings from the initial experiment.

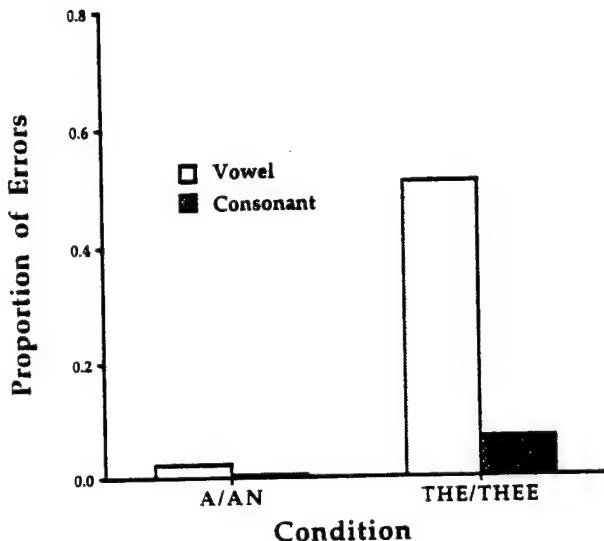


Figure 8. Proportion of errors on nonspecial words beginning with a vowel and on nonspecial words beginning with a consonant as a function of condition.

The effect of word frequency is summarized in Figure 9. It is clear that subjects in the thuh/thee (but not those in the a/an condition) made more errors on low frequency than on high frequency words, in accord with the version of the local model in which subjects attend to word combinations. The effect of word frequency is, however, small, suggesting that subjects attend to other cues as well.

The effect of initial letter/sound category for the special words in stimulus Categories 1 and 2 is shown in Figure 10. Subjects made a greater proportion of errors on words beginning with a consonant letter and a vowel sound (like "honor") than they did on words beginning with a vowel letter and a consonant sound (like "one"). Note that for the a/an condition the error proportions are considerably below the chance level (.50) for words in both initial letter/sound categories but for the thuh/thee condition the error proportions are above chance for words beginning with a consonant letter and a vowel sound although they are below chance for words beginning with a vowel letter and a consonant sound. Also note that the error proportions in Figure 10 for the special words with a mismatch between the initial sound and the initial letter are higher than those in Figures 8 and 9 for the regular words with no mismatch. These findings together indicate that the subjects attended to both the initial sounds and the initial letters of the words, even for the a/an distinction.

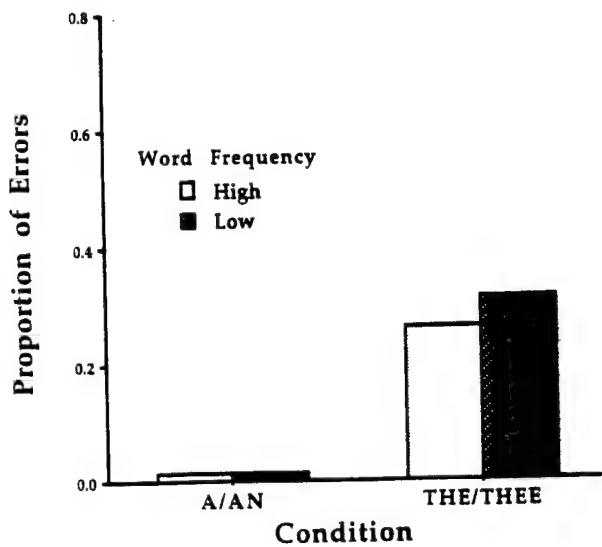


Figure 9. Proportion of errors on high-frequency nonspecial words and on low-frequency nonspecial words as a function of condition.

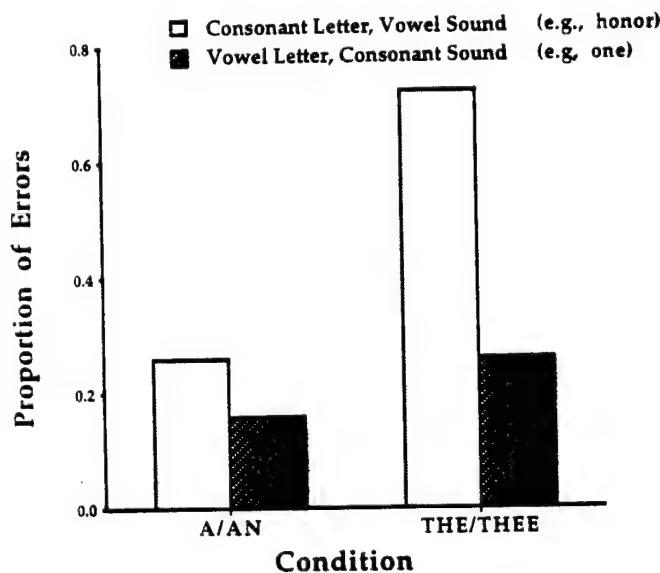


Figure 10. Proportion of errors on special words beginning with a consonant letter and vowel sound and on special words beginning with a vowel letter and consonant sound as a function of condition.

The effects of syllable stress on the special words from stimulus Categories 3 and 4 are summarized in Figure 11. For the words beginning with *h*, subjects made more errors when the first syllable was unstressed than when it was stressed. This effect indicates that subjects are able to discriminate between words on the basis of syllable stress, not just on the basis of

whether the initial phoneme is silent or pronounced, because the initial phoneme was always /h/ for these words.

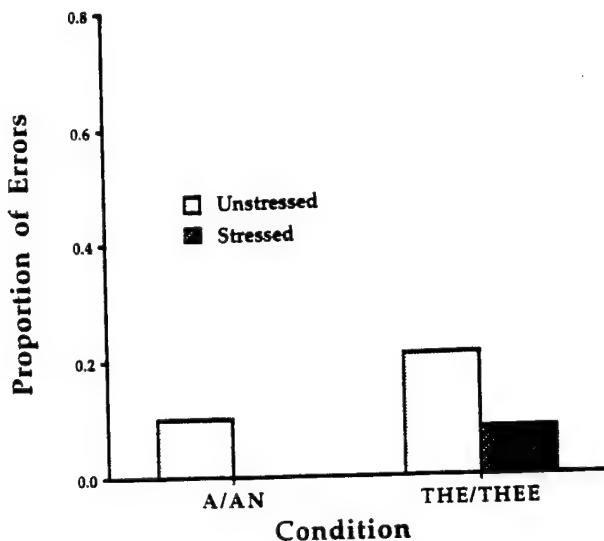


Figure 11. Proportion of errors on special words beginning with the letter *h* and phoneme /*h*/ as a function of condition and stress of the first syllable.

In summary, this experiment not only provided evidence in favor of the local model, but also gave insight into the nature of the local information subjects used. The experiment indicated that subjects made decisions based on the word itself and also on the sound of the initial letter, on the initial letter itself, and on the stress of the initial syllable.

Because we found that even with a clear-cut linguistic distinction that is easily learned, speakers use the local rather than the abstract paradigm for their native language, we recommend that such local knowledge be taught to students during foreign language instruction.

#### Strategy Transitions

In the context of learning linguistic categories, we are also investigating two general kinds of strategy transitions that cognitive psychologists have demonstrated in other tasks (Bourne, Healy, Rickard, & Parker, *in preparation*). First, in concept formation experiments, subjects often adopt an initial strategy of memorizing arbitrary associations between items and responses by rote, but later make a transition to rule-based performance for all items of a given type once a rule is discovered. A second kind of strategy transition, from rule (or algorithm) based performance to direct retrieval (or instance) based performance, has been the focus of our direct research on mental arithmetic (e.g., Rickard, 1996). The more recent research on mental arithmetic raises some important questions about strategy use in second language learning. Under what conditions does practice (that is, experience with the language) result in the abstraction of rules that are then used to guide performance? Under what conditions does rule-based processing eventually give way to instance-based processing? Are there language learning contexts in which rule discovery or rule-based performance is important during the first stages of learning, only to be replaced by instance-based performance as skill with the language improves?

We have completed two experiments which explore these issues using two very different task domains. In the first experiment, 20 subjects were presented strings of three letters one at a time, and they were asked to indicate whether each string was "valid" or "invalid." Validity was determined by a rule unknown to the subject at the onset of the experiment. By the rule, the string is valid only if it can be rearranged to correspond to a sequential string in the alphabet. For example, LMV is invalid, but RQP is valid because it can be rearranged as PQR. A single set of 12 strings (6 valid, 6 invalid) were presented individually and repeatedly for subjects with feedback on their responses over 30 blocks of practice. On every third block, one novel string was presented. Subjects were informed that there was an underlying rule for categorizing the strings which might be useful if discovered, but that their primary goal was to learn to respond as fast and as accurately as possible to each item. Subject strategies were probed after every trial to determine whether they guessed, used a rule, remembered the answer from a previous trial, or did something else.

Accuracy increased steadily from about 52% to around 96%, as shown in Figure 12. Figure 13 shows the proportion of trials on which each strategy was selected, collapsed across all subjects and training problems, and plotted as a function of the block of practice. Although all subjects guessed initially, most subjects soon discovered and started using the rule. However, by Block 6, rule use began to give way to an instance strategy so that by the end of 30 blocks of practice, subjects exhibited the instance-based strategy almost exclusively.

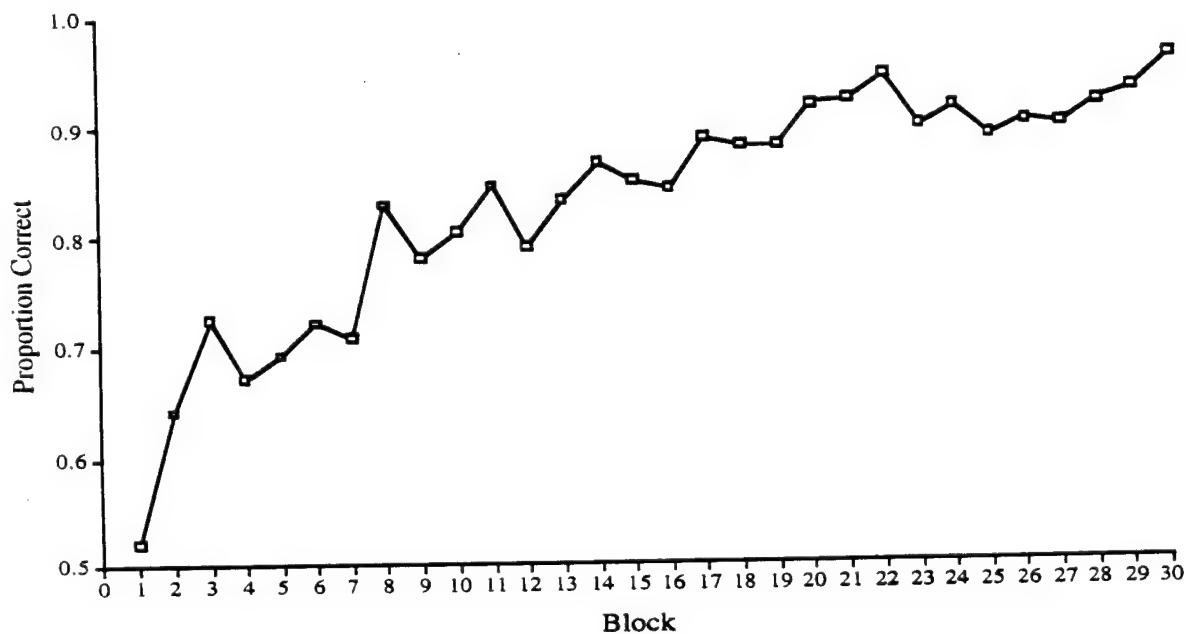


Figure 12. Proportion of correct responses as a function of block in Experiment 1 of strategy transitions study.

Response time patterns provide evidence supporting the validity of the strategy probing data, showing that, as would be expected in this task, performance was slower when the rule was used than when instance memory was used, as shown in Figure 14. It is also interesting to note that response times sped up with practice and the speed-up function was approximately linear for each strategy on a log-log plot.

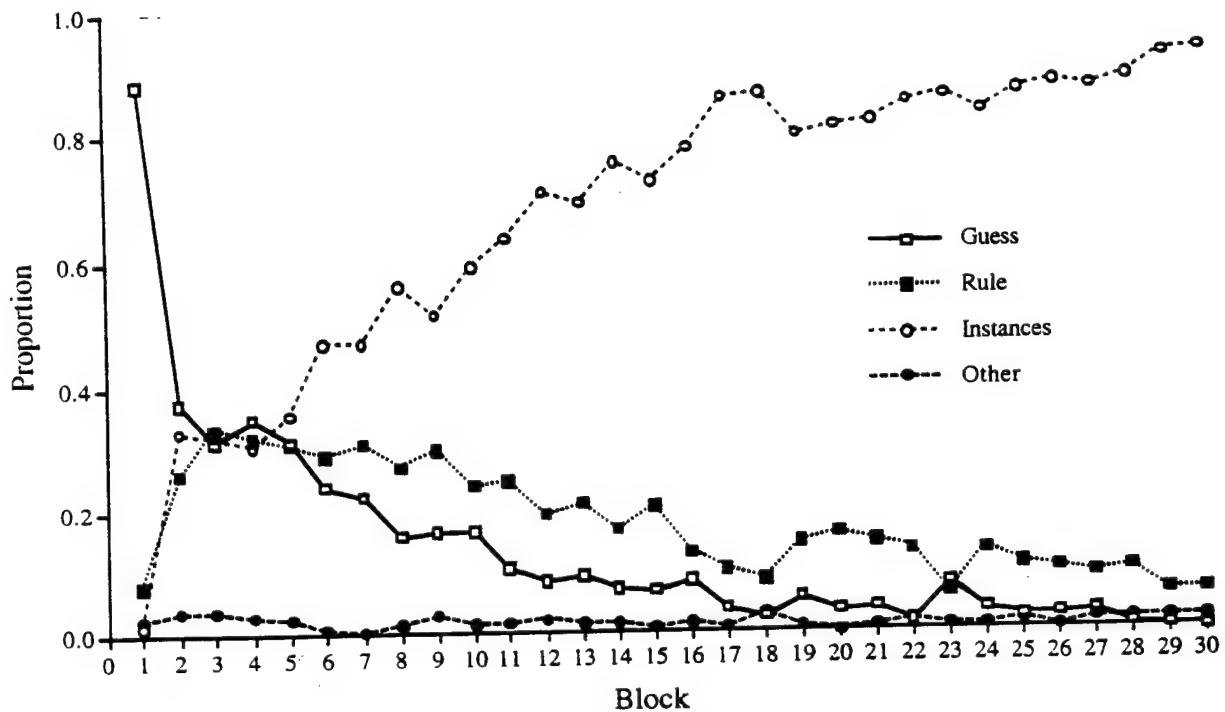


Figure 13. Proportion of trials on which each strategy was selected as a function of block in Experiment 1 of strategy transitions study.

Also in support of the validity of the strategy probing technique, rule was the reported strategy only 18% of the time for old stimuli but 37% of the time for novel stimuli; instances were the reported strategy 67% of the time for old stimuli but only 18% of the time for novel stimuli; and guessing was the reported strategy only 14% of the time for the old stimuli but 45% of the time for the novel stimuli.

The second experiment in this series explored the effects of practice on frequency of use of rule- and instance-based strategies for a natural task, pronunciation of the word *the*. Twenty subjects were presented with frequent English words one at a time, and they were asked to indicate whether the correct pronunciation of *the*, when it precedes the word, is *thuh* or *thee*. Correct performance in this case depended on whether the first sound of the word is a consonant, in which case the correct pronunciation was *thuh*, or a vowel, in which the correct pronunciation was *thee*. This rule was not explicitly introduced to subjects, but, as evident from our earlier study (Healy & Sherrod, 1994), it is likely that it was known to some of the subjects at the outset of the experiment. In analogy to Experiment 1, a single set of 12 words (half requiring the pronunciation *thuh* and half requiring the pronunciation *thee*) were presented repeatedly over 30 blocks of practice with feedback. On every third block, one novel word was presented. Subjects were informed that there was an underlying rule which might be useful if employed, but that their primary goal was to learn to respond as fast and as accurately as possible to each item. As in Experiment 1, subject strategies were probed after every trial.

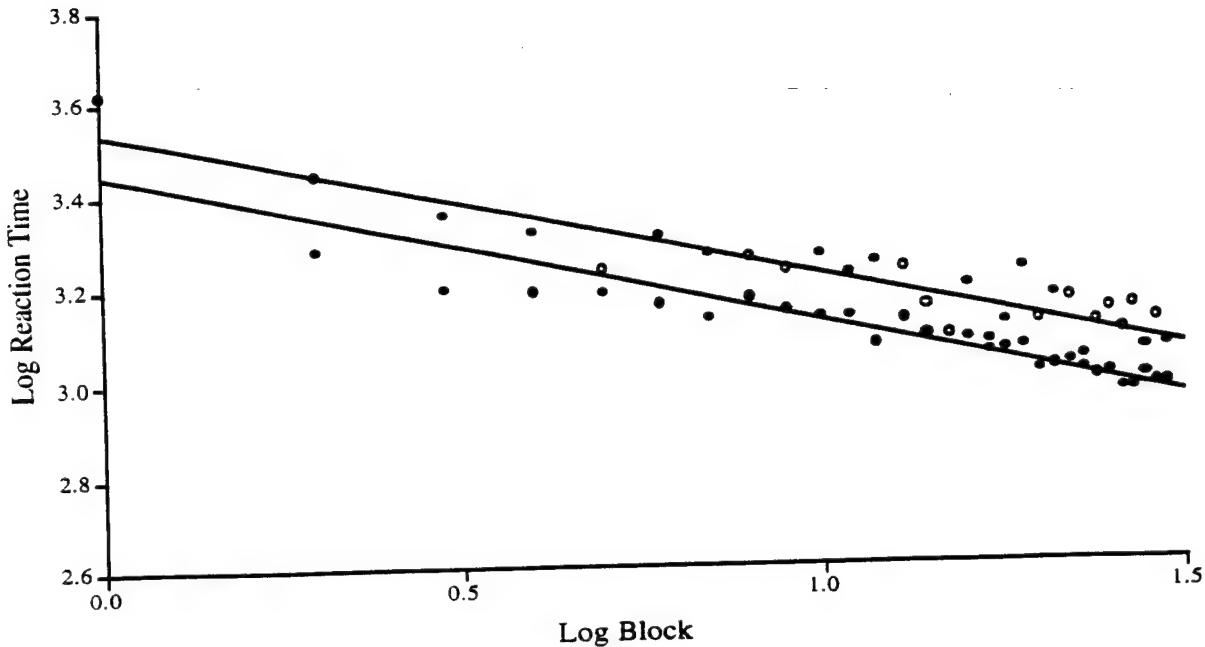


Figure 14. Log reaction time for the rule and instances strategies as a function of log block in Experiment 1 of strategy transitions study.

Accuracy increased from about 80% to around 95%, as shown in Figure 15. Figure 16 shows the proportion of trials on which each strategy was selected, collapsed across all subjects and training items, and plotted as a function of the block of practice. Both rule-based and instance-based strategies were reported approximately 40% of the time initially, suggesting that the rule was indeed known to some subjects at the outset and that pre-experimental experience with specific words resulted in memory traces which could be used to make thuh/thee judgments. Over blocks of practice, however, the rule strategy began to dominate, although instance-based strategies continued to be reported frequently throughout practice. By the end of practice, subjects reported rule use about 65% of the time and instance use about 33% of the time.

As shown in Figure 17, response time patterns provide evidence supporting the validity of the strategy probing data, showing that, in this task, performance was slower when instances were used than when the rule was used. This is the reverse pattern of Experiment 1, but is perhaps to be expected because the rule is much easier to execute in this task. There was a strong mixture of both rule-based and instance-based strategies for both old and novel items throughout practice. Rule was the reported strategy 58% of the time for old problems and 62% of the time for novel problems; instances were the reported strategy 37% of the time for old problems and 27% of the time for novel problems; and guessing was the reported strategy 3% of the time for the old stimuli and 8% of the time for the novel stimuli. These results indicate that a rule was discovered by most subjects during practice, and that use of this rule generalized to new items.

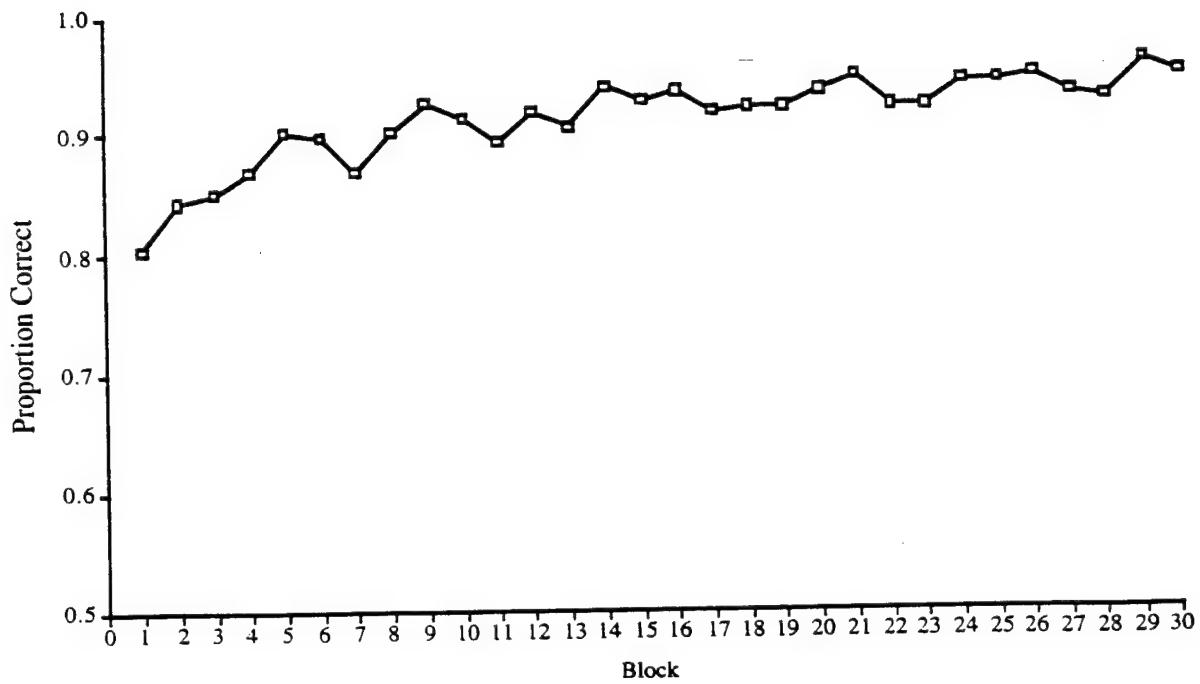


Figure 15. Proportion of correct responses as a function of block in Experiment 2 of strategy transitions study.

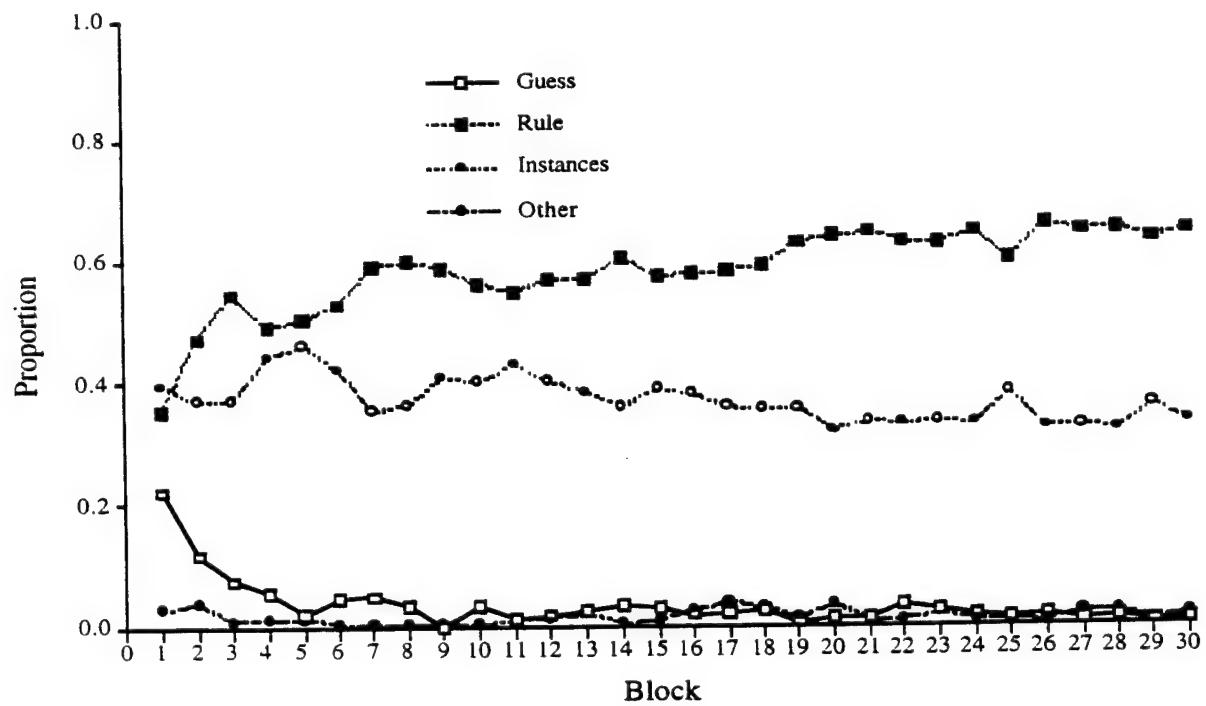


Figure 16. Proportion of trials on which each strategy was selected as a function of block in Experiment 2 of strategy transitions study.

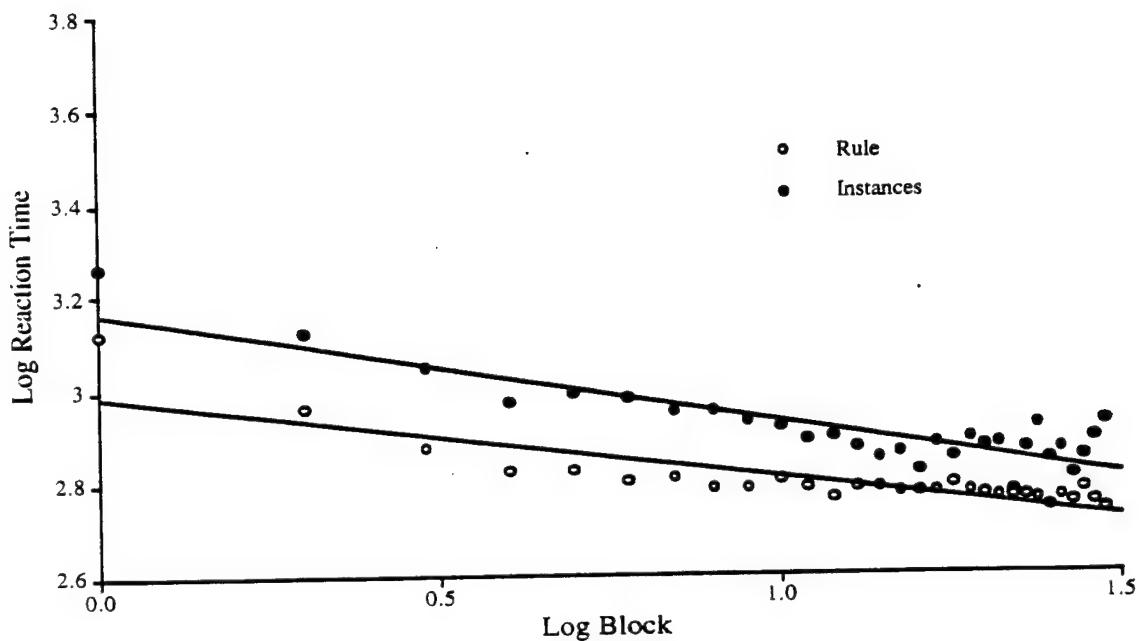


Figure 17. Log reaction time for the rule and instances strategies as a function of log block in Experiment 2 of strategy transitions study.

The results of these experiments differed in which of two strategies became dominant with practice. In the first, which involved artificial strings of letters, instance-based strategies became dominant, whereas in the second, which involved a naturalistic linguistic rule, rule-based strategies dominated. The tasks used in these two experiments differed in three potentially important ways which could have contributed to the strategy use and transitions observed. First, rule difficulty varied, with the rule for the string task being more difficult than the rule for the pronunciation task. Second, the tasks varied in how natural they were, with the rule for the string task being arbitrary and artificial and the rule for the pronunciation task being a part of natural language skill. Third, the rule in the string task was unknown to any subject in advance of the experiment, whereas the rule in the linguistic task was at least partially known to all subjects in advance. In our current research, we are examining these three differences to determine which of them is crucial in determining the strategy that eventually dominates.

#### Functional Units of Language

##### Functional Units in Reading

We have been using a simple letter-detection task to identify the functional units of language involved in reading text (see Healy, 1994, for a summary). The basic letter-detection task involves subjects reading text and circling each instance of a target letter. One striking finding from this task is that subjects make an extremely large proportion of errors on very common words like the. Drewnowski and Healy (1977) proposed a set of "unitization" hypotheses to account for such findings. According to these hypotheses, we can identify higher-order units, such as syllables, words, or

even short phrases, without having to complete letter identification. The identification of these higher-order units is facilitated by familiarity. For example, common words are identified as units more easily than rare words. Because letter identification is not always completed for very familiar words like *the*, many letter detection errors are made on those words.

The size of the functional units used in reading text has been shown in earlier studies to depend on the reading ability of the subjects; the size of the units increases as the subjects' reading ability increases (Cunningham, Healy, Kanengiser, Chizzick, & Willitts, 1988; Drewnowski, 1978, 1981). These earlier studies have been limited, however, to developmental investigations with children. It seems likely that the reading units used by adults would also vary in their size depending on the individuals' fluency in the language of the text. In the initial stages of foreign language learning, the size of the functional units might be quite small and limited relative to those of the native language. We refer to this as the "limited unit" hypothesis. Alternatively, the size of the units used in a foreign language may coincide with those employed in the native language. We refer to this as the "full transfer" hypothesis.

Because it is crucial to focus an instructional program on the most appropriate functional units, it seems important to determine which of these alternative hypotheses governs the size of the units used when a person reads in a foreign language. Towards that end, we have conducted three experiments that employ the letter detection paradigm. In the first experiment (Buck-Gengler & Healy, 1995), subjects were divided into eight groups which varied in their experience with the German language, and the texts read by them were in German. One group of subjects consisted of native English speaking undergraduates who had no training in German. Six groups consisted of native English speaking undergraduates currently taking a course in German. There were five different levels of German courses employed, and students in the first level were divided into those who had not and those who had previously studied German. The last group of subjects were native speakers of German. For a subset of the students, we had verbal SAT scores, which we used as an index of their reading proficiency in English.

The passage subjects read was a short story in German. The target letter was *d*, and the high frequency test words containing *d* were the German definite articles and the German word for "and." According to the limited unit hypothesis, the size of the units employed should be a direct function of the subjects' fluency in the language they are reading, German, whereas according to the full transfer hypothesis, the size of the units used should be a direct function of the subjects' fluency in their native language, English.

The results are summarized in Figure 18. Fluency in German did indeed determine the magnitude of the difference between errors on high and low frequency test words, with a bigger difference as German level increased, in accordance with the limited unit hypothesis.

A further test of this hypothesis is provided by the data from the students who had SAT scores available. We found that fluency in English, as reflected in SAT scores, did not have any clear relation to the pattern of errors on high and low frequency test words, which is also consistent with the limited unit hypothesis.

In the second experiment (Buck-Gengler, Romero, Healy, & Bourne, in preparation), subjects were asked to read and detect target letters in normal English text. The subjects were students of ESL from two different populations: native speakers of languages that use the Roman alphabet (as does English) and native speakers of languages that use alphabets other than Roman (for example, Japanese). One prediction of the limited unit hypothesis is that the functional unit will be larger for subjects whose first language uses the Roman alphabet, than for subjects whose first language does not use the

Roman alphabet. Subjects read a short prose passage and searched for the target *h*. The high-frequency test word was "the."

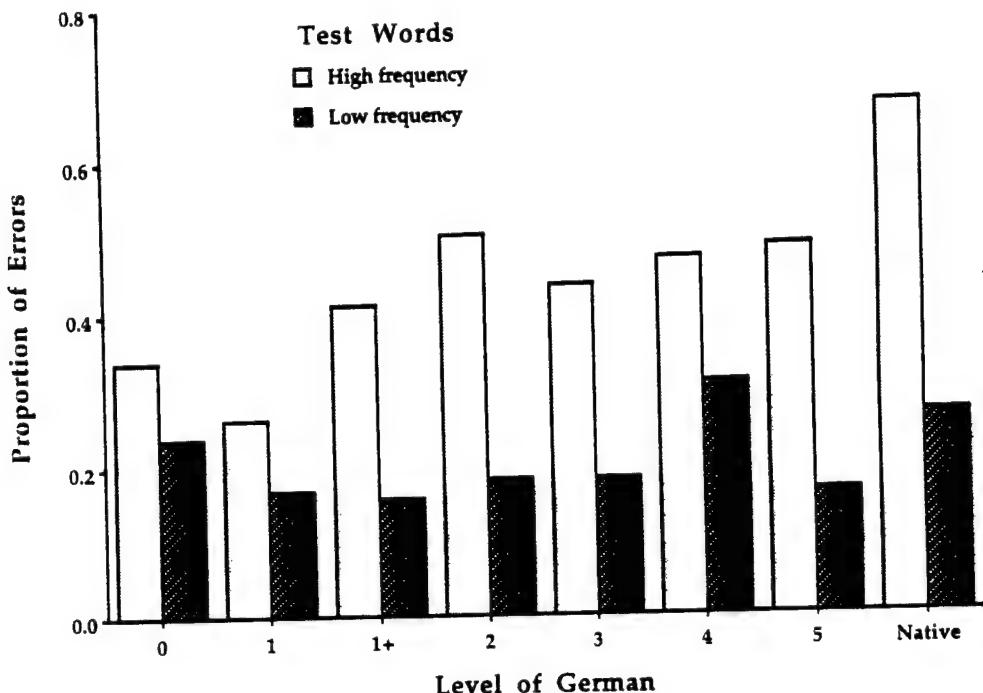


Figure 18. Proportion of letter detection errors as a function of test word frequency and fluency level of German.

As shown in Figure 19, the unitization effect (i.e., the high proportion of detection errors on *the* relative to that on other words) was larger for subjects whose first language used the Roman alphabet than for subjects whose first language used a non-Roman alphabet. This effect of first-language alphabet has important implications for foreign language instruction, because it implies that the instruction should depend at least to some extent on the nature of the students' first language and its similarity to the foreign language they are learning.

We conducted a third experiment that employs the letter detection paradigm with native speakers of Chinese and English (Tao, Healy, & Bourne, in press). Five different participant groups were tested. Three groups were native speakers of Chinese; the first of these groups was tested in Beijing, China and consisted of elementary school children who recently completed first- or second-grade and who had no exposure to English although they were familiar with the English alphabet because it is used as a phonetic spelling system with Chinese pronunciation. The second group of native Chinese speakers was also tested in Beijing and consisted of adults who had learned English in high school but did not use English much in their daily activities. The third group of native Chinese speakers was tested in Hong Kong and Taipei, Taiwan at two international linguistic conferences and consisted of linguists who had received doctorate degrees from either the United States or Great Britain. They were approximately the same age as the other Chinese adults. The last two groups of participants were native English speakers tested in Boulder, Colorado. One of these groups consisted of University of Colorado

undergraduates, and the other consisted of faculty members at the University of Colorado, who had doctorate degrees in Linguistics, Religious Studies, or Psychology.

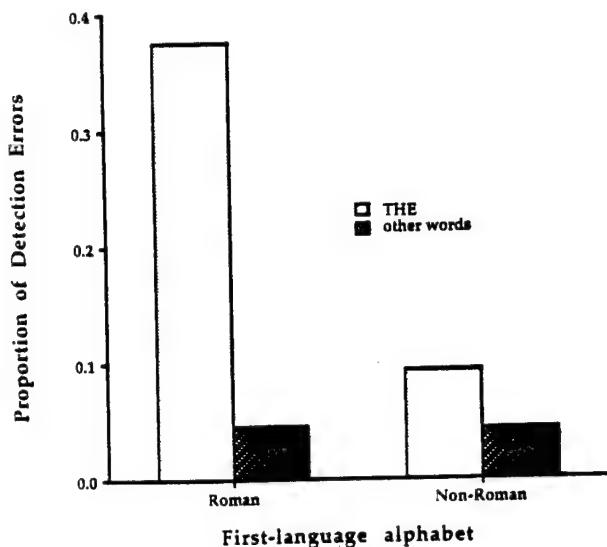


Figure 19. Proportion of letter detection errors as a function of test word and first-language alphabet.

Each participant was given the letter detection task illustrated earlier with the target letter *h*. The results are summarized in Figure 20 in terms of proportions of detection errors for the word *the* and for other (less familiar) test words as a function of participant group.

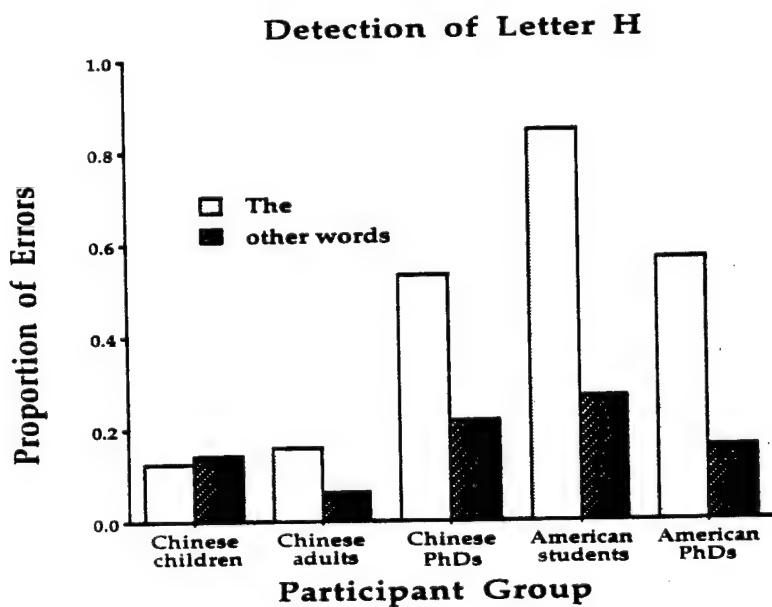


Figure 20. Proportion of letter detection errors as a function of test word and participant group.

The Chinese children with essentially no previous exposure to English showed no difference in error rates between the word the and the other test words, whereas the Chinese adults who knew English but did not use it frequently showed a small, nonsignificant effect of unitization -- namely, a greater proportion of errors on the than on other test words. In contrast, the other three groups tested, all of whom were fluent in English, showed large, reliable effects of unitization. These findings are consistent with the limited unit hypothesis, according to which reading units vary in their size depending on the readers' fluency in the language of the text.

#### Functional Units in Memory

In earlier work (Schneider, Healy, Ericsson, & Bourne, 1989), we used a version of the letter detection task as a means to illuminate the memory representations of stored text material. Specifically, subjects memorized short texts and then searched memory for target letters in the texts, writing down every word in sequence that contained a target. This task, which relied on memory, was compared to on-line visual and auditory baseline tasks in which subjects either read or heard texts and wrote down every word containing a target as they were encountered. For the visual baseline task, subjects showed the typical signs of unitization found with the standard procedures; that is, they missed more targets in common than in rare words. In contrast, there was no difference between errors on common and rare words for the auditory baseline task. We found striking individual differences in the pattern of errors on the memory task, and these differences were related to subjects' retrospective verbal reports concerning the memory representation they used to store the text. Those subjects who said that they searched a visual, or image, representation of the text in memory showed the standard unitization pattern (i.e., they missed more targets in common than in rare words), whereas those subjects who said that they searched an auditory, or spoken, representation of the text in memory showed an error pattern similar to that found in the auditory baseline condition (i.e., no difference between errors on common and rare words).

This work suggests that it may be important when teaching students a foreign language to keep in mind that individuals differ in their preferred memory representation and that the memory representation they select may determine the optimal training strategy. In a new pair of experiments (Schneider, Healy, & Steinhart, 1996), we started by replicating this evidence for individual differences in memory representation.

Subjects were shown a short passage to memorize across five successive study-test memorization trials. By the last trial, all subjects wrote down the passage from memory without any errors. After memorization, they were asked to search through their memory representation of the passage and write down every word that contains the target letter h.

We divided subjects into two groups depending on their retrospective report concerning memory type--auditory and visual. In accordance with the findings in our earlier study, we expected subjects in the visual group but not those in the auditory group to show the typical signs of visual unitization--namely, more detection errors on the common word the than on other words containing an h. As evident from Figure 21, which summarizes our results, this prediction was confirmed.

The aim of our next experiment was to reveal how flexible is the subjects' choice of memory representation. To assess flexibility, we varied the instructions given to subjects concerning the memory representation they should adopt. In one condition, we instructed subjects to use a visual memory representation and in another condition we instructed them to use an auditory memory representation. If the memory representation is flexible, then subjects in the visual instruction group should show the pattern of letter

detection errors found for subjects who report using a visual memory representation, and subjects in the auditory instruction group should show the pattern of letter detection errors found for subjects who report using an auditory memory representation.

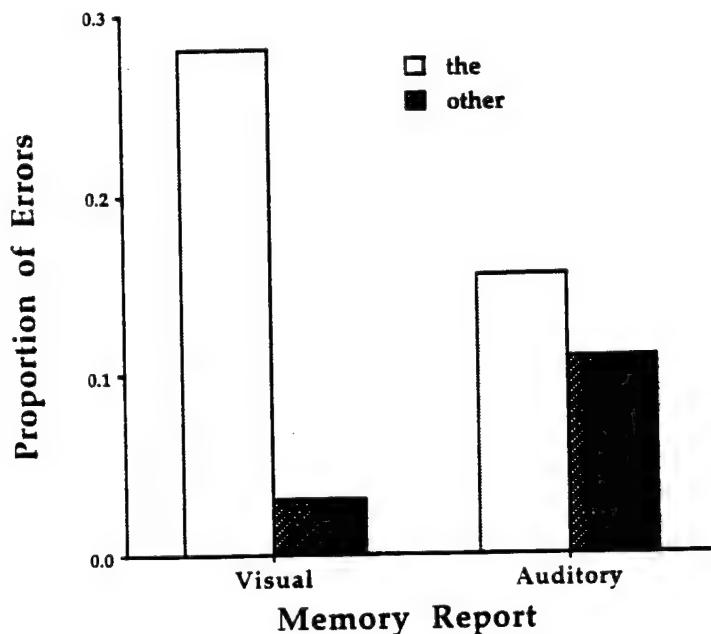


Figure 21. Proportion of memory detection errors as a function of test word and reported memory representation.

Our experiment yielded strong evidence for flexibility. The results are summarized in Figure 22.

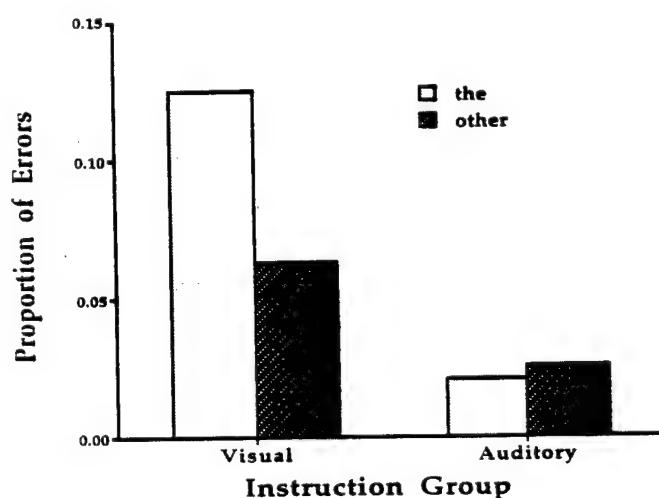


Figure 22. Proportion of memory detection errors as a function of test word and instructed memory representation.

Subjects in the visual instruction group, but not those in the auditory instruction group, made more detection errors on the common word the than on other words containing an h. We also found that the instructions influenced errors on the five memorization trials preceding detection. Subjects in the auditory instruction group made almost four times as many content word or phrase substitutions ( $M = 1.708$ ) during memorization as did subjects in the visual instruction group ( $M = .458$ ). A possible explanation for this finding is that content word or phrase substitutions result largely from a reconstruction process that occurs when subjects visualize the scene described by the passage rather than the words in the passage. This reconstruction process would seem more likely to occur for subjects hearing the words in the passage than for those seeing the words in the passage because it would be difficult to visualize the scene and the words at the same time. In any event, these results provide evidence that the instructions affected the memory representation used at the time of encoding as well as that used at the time of retrieval.

More generally, our findings suggest that subjects do indeed have control over the memory representation they use to store text information and that the chosen representation may profoundly affect what they can retrieve from memory. The implication for foreign language training is that instructors may influence not only what is learned by subjects but also how it is stored in memory. Instructors should advise students to use the representation that would be most helpful given their particular subsequent retrieval needs. Because these needs are probably difficult to anticipate, it may be best to encourage students to adopt multiple forms of memory representation.

#### Message Comprehensibility

##### Air-Ground Communication

The last issue we shall discuss involves message comprehensibility. Nonnative speakers of a language often comment on the high speed with which native speakers talk. When listening to a foreign language, nonnative speakers often are unable to tell where one word ends and another begins. We have all been in situations where we had to ask a speaker to slow down or to repeat one item at a time when specific instructions were involved. These shared experiences suggest that both the rate of speech and the number of propositions spoken affect comprehension.

Speech rate and the number of propositions in an utterance may interact in crucial ways to affect comprehension and retention of the utterance. In the present study, we examine this interaction. To focus our investigation, we explore this issue in a specific concrete domain in which the problem has potentially fatal consequences, namely communication between air crews and air traffic controllers.

To begin our research, we conducted a detailed analysis of an actual half-hour recording of air-ground communication at an international airport (Barshi, in preparation). This analysis revealed two main findings. First, flight crews were only likely to misunderstand the air-traffic controllers' instructions when these instructions included four or more propositions; such misunderstandings did not occur when the instructions were shorter. Second, among the long instructions, more misunderstandings occurred when the speech rate was fast than when it was slow. The following is an example from this recording of a partial and erroneous pilot's read back of instructions given by a controller. The controller instructed the crew: "Expo nine two you're niner miles from Laker, turn left heading three one zero, maintain three thousand till established on the localizer, cleared ILS runway two eight right approach, maintain one seven zero knots until Laker." To which the pilot responded, "That's two one, uh zero on the heading and, uh- one seventy till

Laker." The pilot read back the wrong compass heading (he said "two one zero" instead of "three one zero") but the correct speed. He also neglected to acknowledge the altitude restriction and the approach clearance and omitted the aircraft identification. This omission prevented the controller from ascertaining that the correct crew received the correct clearance. Such a partial and erroneous readback is potentially hazardous and could lead to a fatal accident.

We assume that the proposition is the functional unit of language most relevant to our study. Further, we assume that speech rate should be decomposed into two components, the first involving the rate at which individual items are uttered and the second the duration of the pauses separating contiguous items. In our experiments, we independently manipulate the number of propositions contained in each message, the duration of each word, and the pause duration separating successive words. A read-back procedure analogous to that used by pilots allows us to test for retention, and the implementation of the instructions given provides us with a strict test for comprehension.

Specifically, in our task, subjects hear instructions, repeat the instructions aloud, and then follow them. The instructions describe movements in a simulated three-dimensional space on a computer screen, including four grids stacked one on top of another. A sample instruction including three propositions is the following: "Turn left two squares; climb down one level; move forward one step." The subject hears and then immediately repeats this instruction. Next, to demonstrate comprehension, the subject uses the computer mouse to follow the instructions, by clicking each appropriate square on the grid in the order specified. In the instructions, we employ two speech rates and six utterance lengths, varying from one to six propositions. Subjects progress through practice trials followed by six blocks of experimental trials. To assess the effect of number of propositions, we measure how accurately the subjects are able to follow the instructions. This measure reflects both the subjects' memory for the propositions and their ability to act on those propositions. (Although these two aspects of performance are confounded in the present study, we plan to examine them separately in future studies.)

In our first experiment (Barshi, 1995), speech rate was manipulated by varying only the pause duration between words, from 0 to 1/2 second. The results are summarized in Figure 23. There was a large effect of the number of propositions, and a smaller but significant interaction of rate and number of propositions.

As shown in Figure 24, subjects improved significantly as they progressed through the six blocks of trials, with a greater improvement evident for the intermediate number of propositions. These results suggest that three propositions is a good estimate for maximum communication efficiency but the degree of experience is an important factor in this estimate.

In follow-up experiments (Barshi & Healy, in preparation-a), as in our first experiment, we found large effects on comprehension accuracy of the number of propositions in the message but essentially no effects of speech rate, whether we varied rate by manipulating the pause duration between words or the duration of the words themselves.

The instructional messages used in aviation contain redundant elements. For instance, pilots may be told to "turn left, heading three-one-zero," in which the words "turn" and "heading" might seem unnecessary. We wondered whether such redundancy would affect message comprehensibility. In a subsequent experiment (Barshi & Healy, in preparation-a), we compared redundant messages of the type described earlier to messages half the length including only the critical words. For example, with the redundant format the subjects were instructed, "Turn left two squares; climb down one level; move

forward one step," whereas with the comparable minimal message the subjects were simply told, "Left two; down one; forward one."

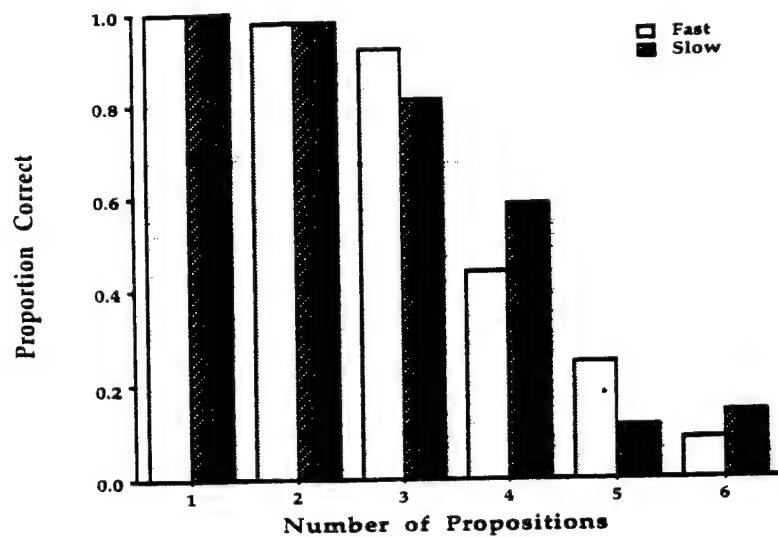


Figure 23. Proportion of correct responses as a function of speech rate and number of propositions.

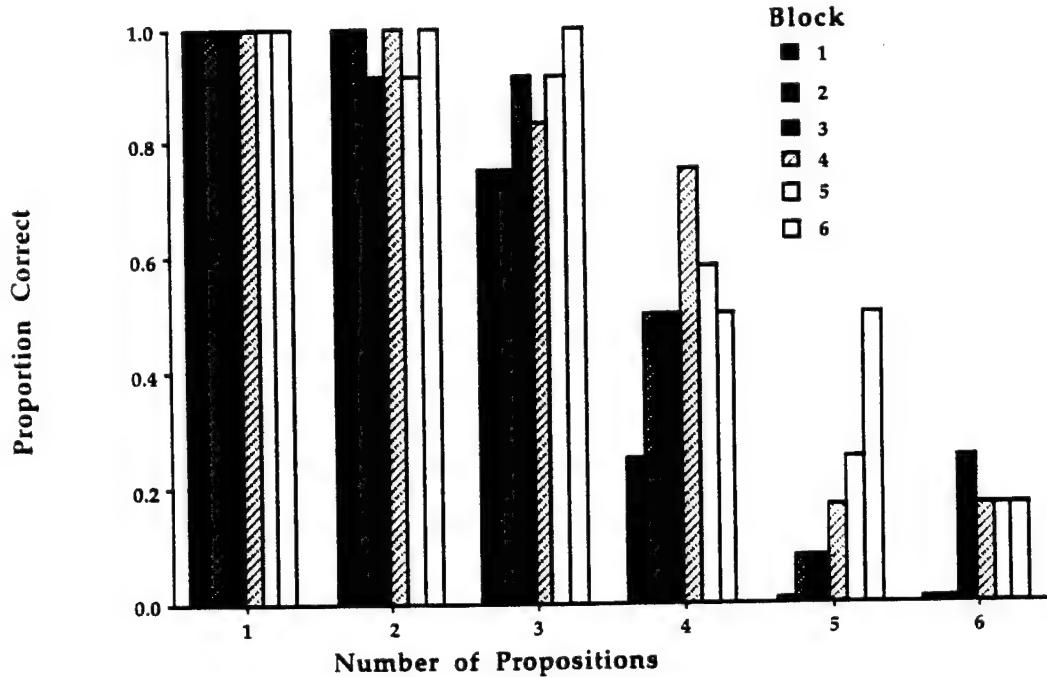


Figure 24. Proportion of correct responses as a function of block and number of propositions.

The results are shown in Figure 25. As in our initial experiments, we found a large effect of the number of propositions, but we found essentially no effect of message redundancy. Note in particular, that there was a very steep increase in the proportion of errors as the messages increased from three to six propositions, but there was virtually no change in the proportion of errors as the messages were shortened from the redundant four words per proposition to the minimal two words per proposition, even though the change in the number of words was as great for the doubling of propositions as for the redundancy manipulation. Although in our laboratory task, the redundant words add no meaning, in an actual flight situation redundancy is advantageous because it clarifies potential ambiguities. For example, in the instruction "turn left, heading three-one-zero," the word "heading" may seem unnecessary. However, the numbers "three one zero" could represent a compass heading of 310 degrees, a speed of 310 knots, or an altitude of 31,000 feet. Thus, the word "heading" is needed to disambiguate this message. Hence, we interpret our findings of no disadvantage in performance for longer redundant messages to imply that controllers should use some redundancy to avoid potential ambiguities, because minimal messages do not improve performance.

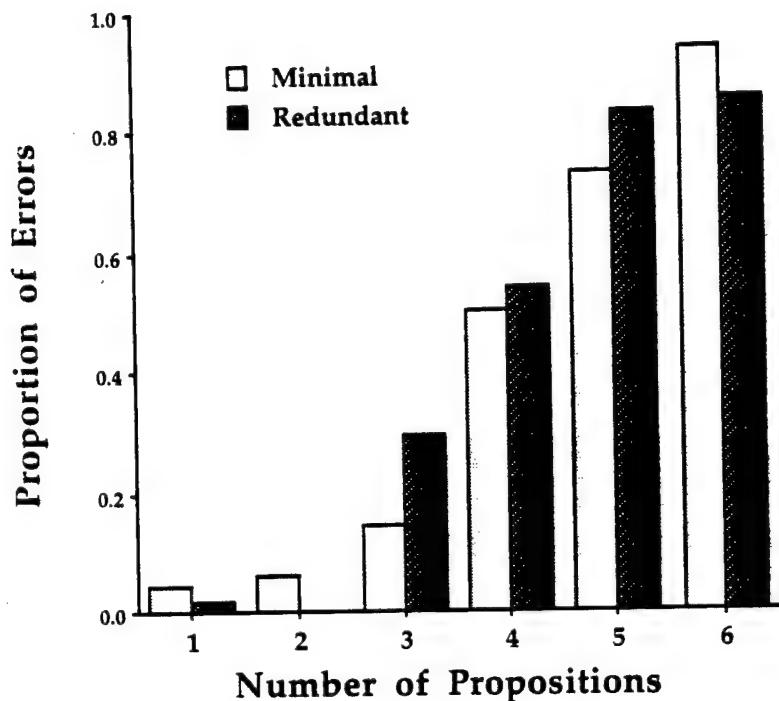


Figure 25. Proportion of errors as a function of message redundancy and number of propositions.

Finding an effect of number of propositions is not surprising because with each additional proposition, there is an additional memory load and performance requirement. To determine whether number of propositions has a list-length effect (i.e., affects memory for and performance on a single proposition), we also examined the proportion of errors on the first proposition alone. The results are shown in Figure 26. It is clear that

there is a large list length effect even when only the first proposition is examined and still no effect of message redundancy.

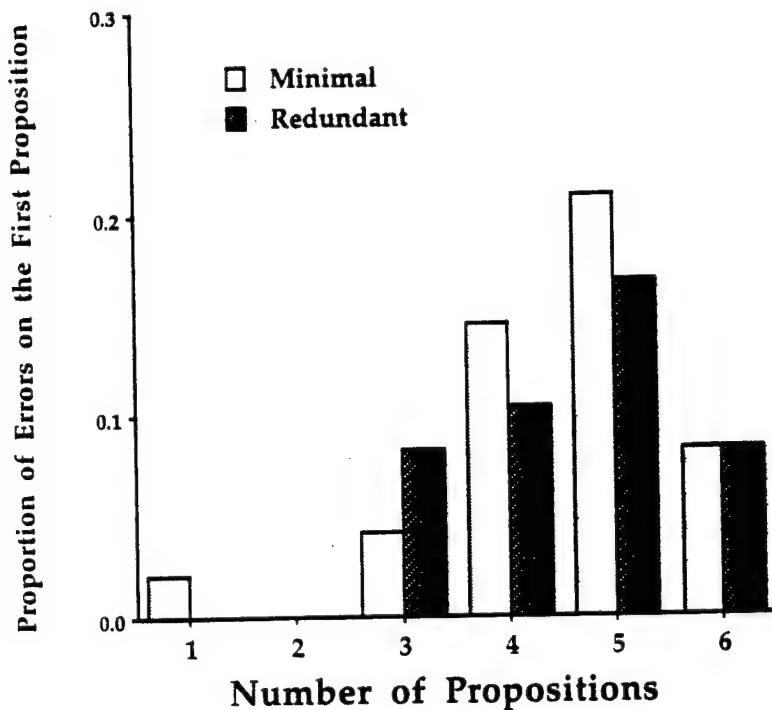


Figure 26. Proportion of errors on the first proportion only as a function of message redundancy and number of propositions.

In these initial experiments, we employed only native speakers of English. However, because English is the international language of aviation, there are many situations in which pilots are nonnative speakers of English. Hence, in our next series of experiments (Barshi & Healy, *in preparation-b*), we examined situations in which the listeners were nonnative English speakers. We wondered whether a slow speech rate and a high message redundancy would improve performance in such situations. We have completed three experiments, which paralleled three of our earlier experiments, the first varying speech rate by manipulating the pause duration between words, the second varying speech rate by manipulating the length of the words themselves, and the third varying message redundancy in the manner just described. In each of these experiments, we tested 6 native and 12 nonnative speakers of English. We used a median split procedure to divide the nonnative speakers into low-fluency and high-fluency groups on the basis of their performance on a listening comprehension test, which was a computerized test that we developed based on the listening comprehension portion of the TOEFL test. This test of English as a foreign language is used by United States universities to assess the English proficiency of foreign applicants for undergraduate and graduate studies. In our test, participants heard 10 spoken sentences; for each one they were shown on the computer screen four sentences and were asked to select the one sentence closest in meaning to the one they heard.

In Experiment 1, speech rate was either slow (i.e., there was a 750 ms pause inserted between words) or fast (i.e., there was no added pause between

words), and message length varied from one to six propositions. The results are shown in Figure 27 in terms of proportion of errors as a function of message length and fluency level.

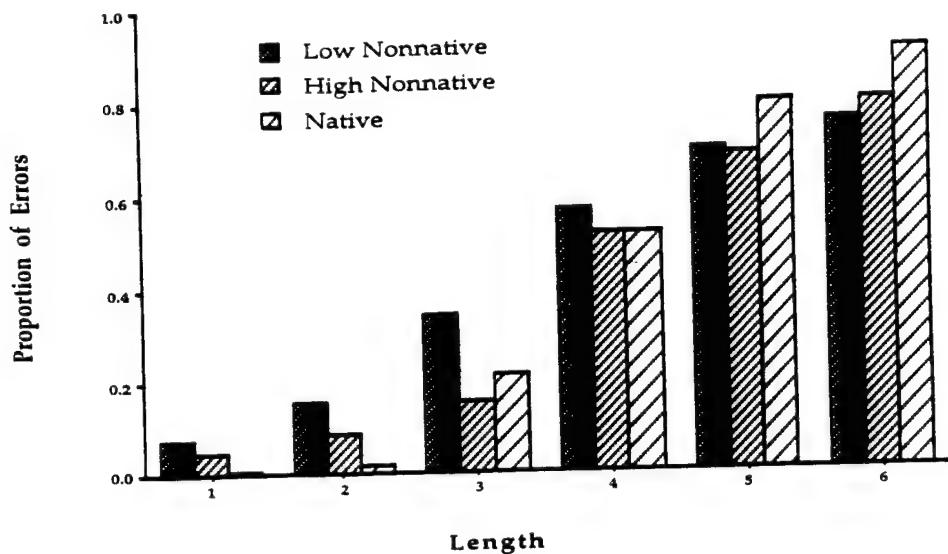


Figure 27. Proportion of errors as a function of message length and fluency level in Experiment 1 of the study involving nonnative speakers of English.

It is clear that message length had a very large effect for each fluency level. Again, to determine whether message length has a list-length effect in this situation, we also examined the proportion of errors on the first proposition alone. Figure 28 shows that this effect of message length occurs even when only errors on the first proposition are examined.

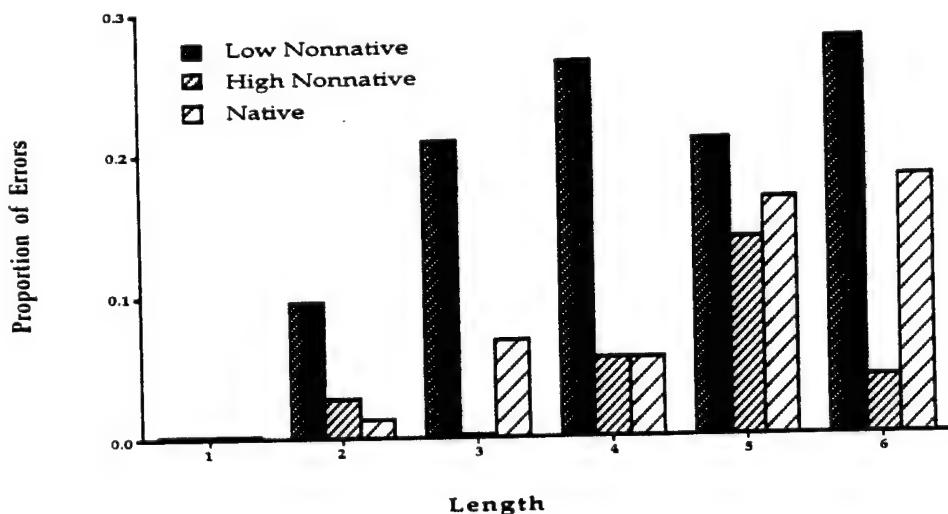


Figure 28. Proportion of errors on the first proposition only as a function of message length and fluency level in Experiment 1 of the study involving nonnative speakers of English.

Figure 29 shows the proportion of errors as a function of speech rate and fluency level. Speech rate had minimal and nonsignificant effects, even for the low fluency group of participants.

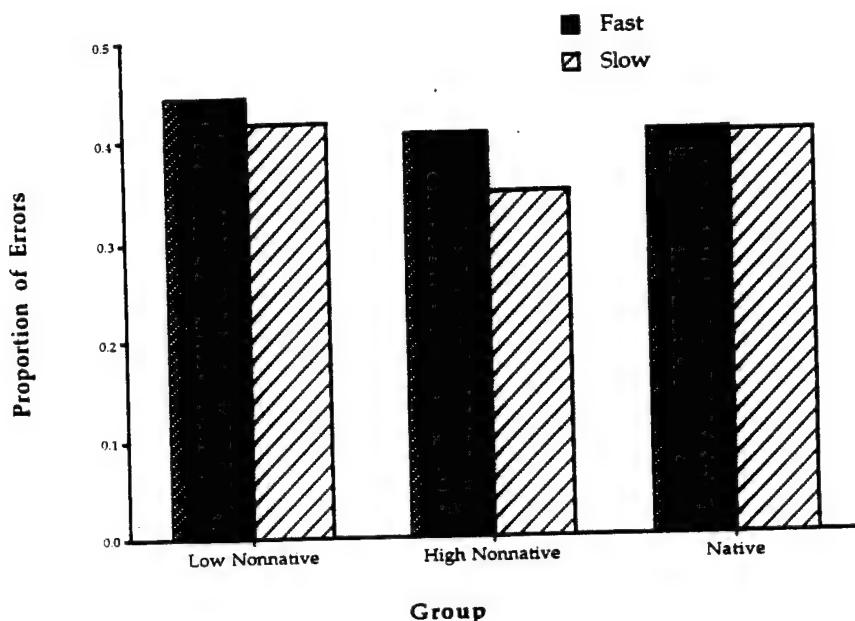


Figure 29. Proportion of errors as a function of speech rate and fluency level in Experiment 1 of the study involving nonnative speakers of English.

In Experiment 2, we compared normal speech with compressed speech, in which each word was compressed to either 50% or 75% of its original length, while maintaining intelligibility. Again, message length varied from one to six propositions. The results are shown in Figure 30 in terms of proportion of errors as a function of message length and fluency level. The low fluency group made more errors overall. Message length had a very large effect for each fluency level. In addition, there was a significant interaction of fluency level and message length, because the disadvantage for the low fluency group was greatest at the shorter message lengths. Figure 31 shows that both main effects of fluency and of message length occur even when only errors on the first proposition are examined. Figure 32 shows the proportion of errors as a function of speech rate and fluency level. Again speech rate had minimal and nonsignificant effects, even though we used compressed speech which we expected to pose problems for nonnative speakers.

In Experiment 3, we compared redundant messages, such as "Turn left two squares," with the corresponding minimal messages, such as "Left two." Again, message length varied from one to six propositions. The results are shown in Figure 33 in terms of proportion of errors as a function of message length and fluency level. Once again message length had a very large effect for each fluency level. Note in particular that there was a very steep increase in the proportion of errors as the message length was doubled by increasing from two to four propositions. Figure 34 shows that this effect of message length occurs even when only errors on the first proposition are examined. In contrast, as shown in Figure 35, for all three fluency levels there was virtually no change in the proportion of errors as the messages were shortened from the redundant four words per proposition to the minimal two words per

proposition, even though the change in the number of words was as great for the redundancy manipulation as for the doubling of propositions.

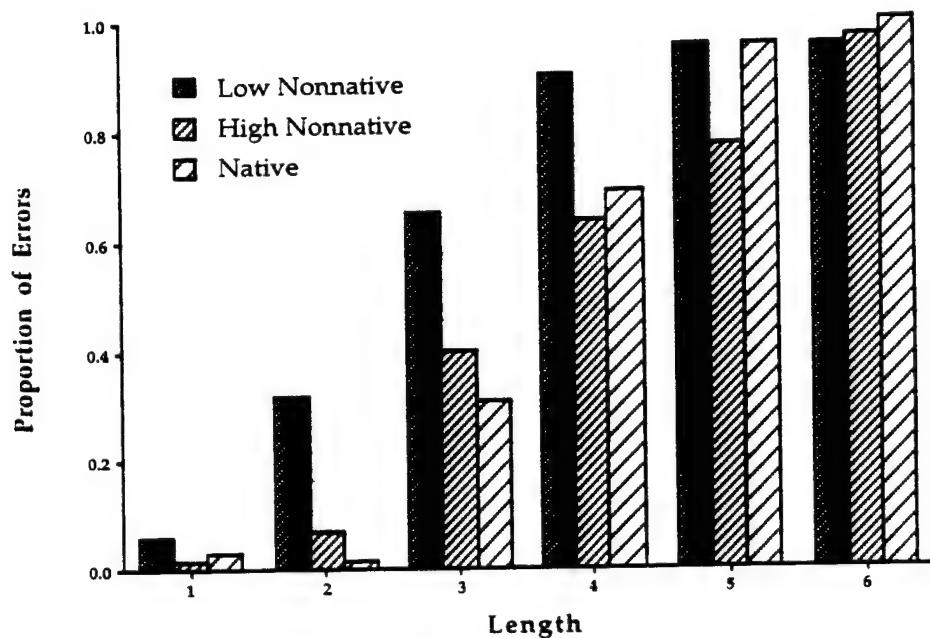


Figure 30. Proportion of errors as a function of message length and fluency level in Experiment 2 of the study involving nonnative speakers of English.

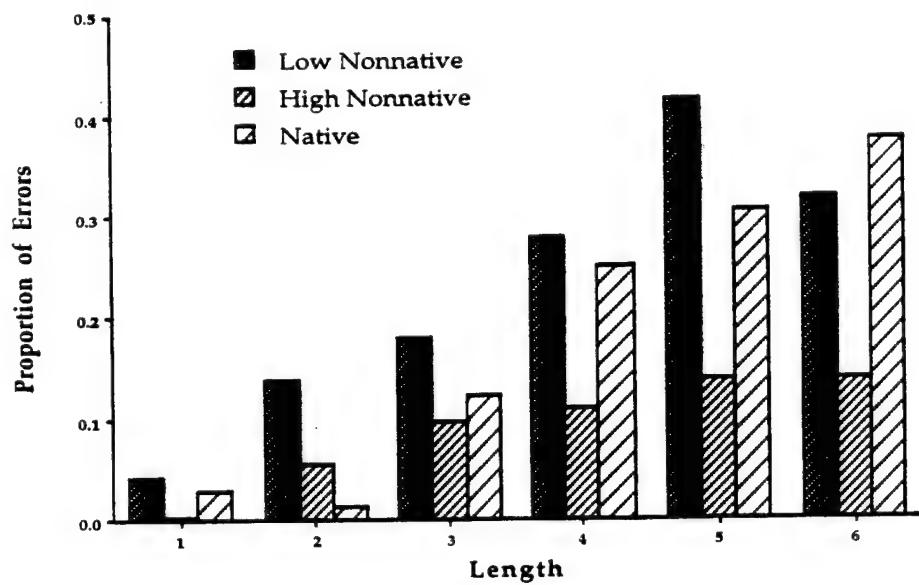


Figure 31. Proportion of errors on the first proposition only as a function of message length and fluency level in Experiment 2 of the study involving nonnative speakers of English.

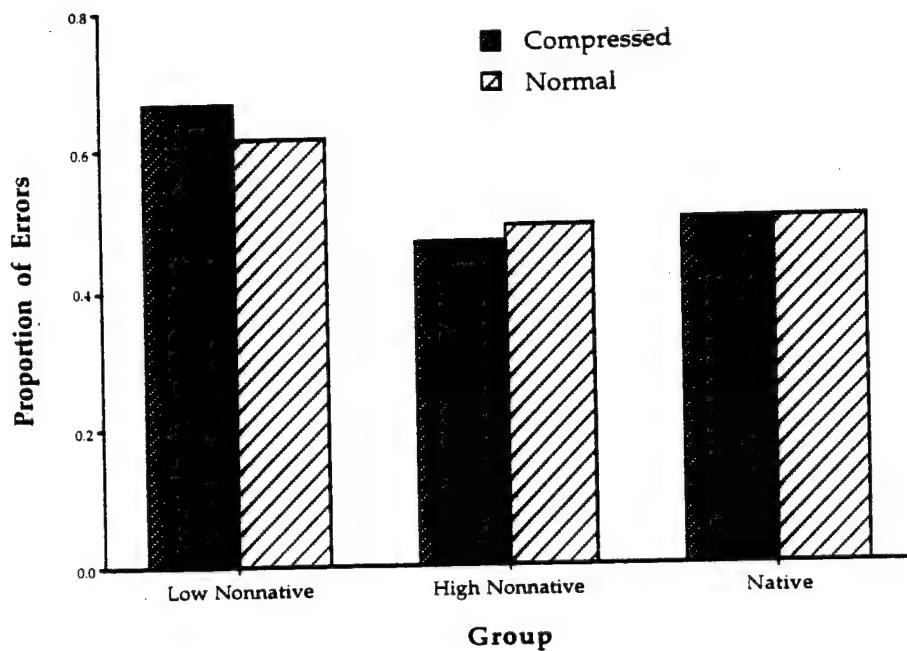


Figure 32. Proportion of errors as a function of speech rate and fluency level in Experiment 2 of the study involving nonnative speakers of English.

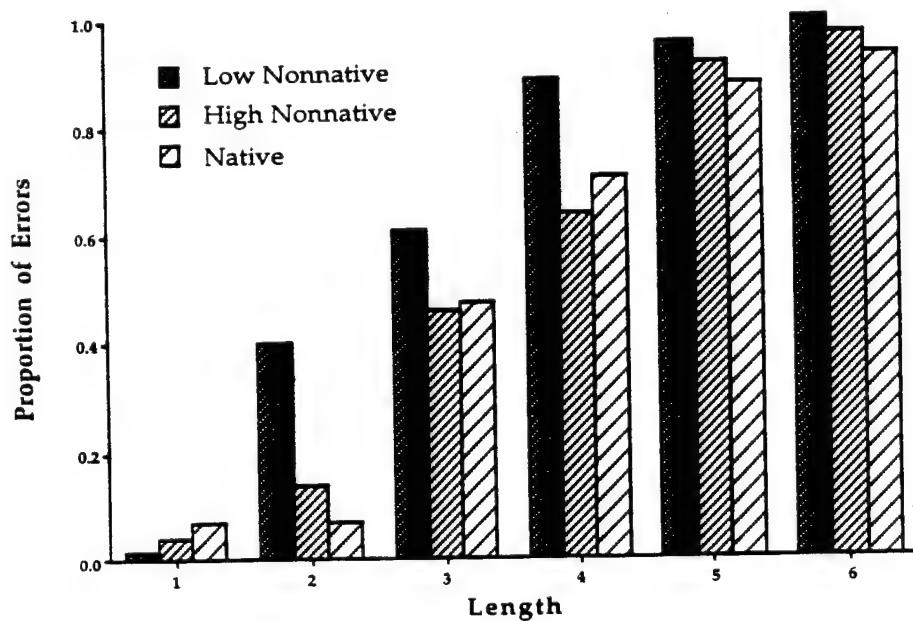


Figure 33. Proportion of errors as a function of message length and fluency level in Experiment 3 of the study involving nonnative speakers of English.

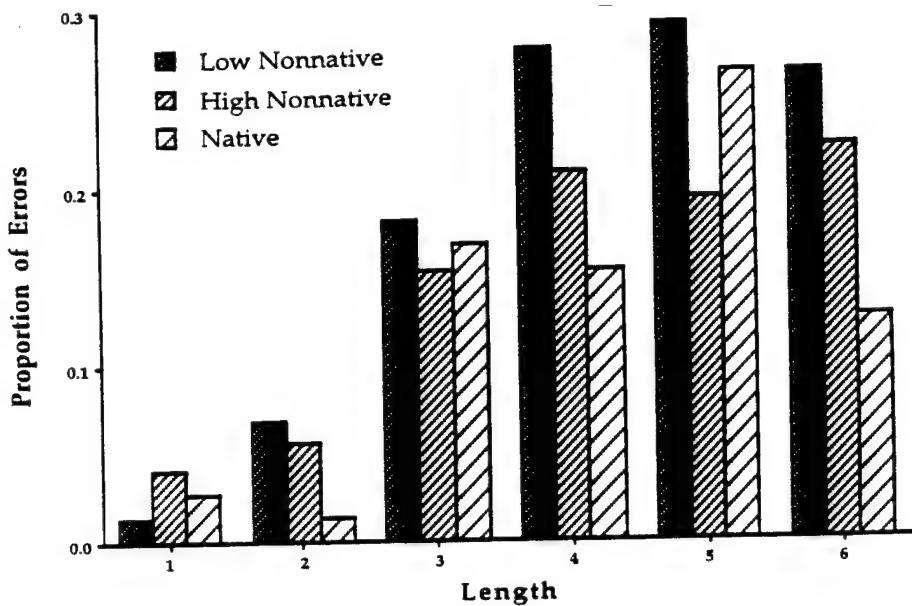


Figure 34. Proportion of errors on the first proposition only as a function of message length and fluency level in Experiment 3 of the study involving nonnative speakers of English.

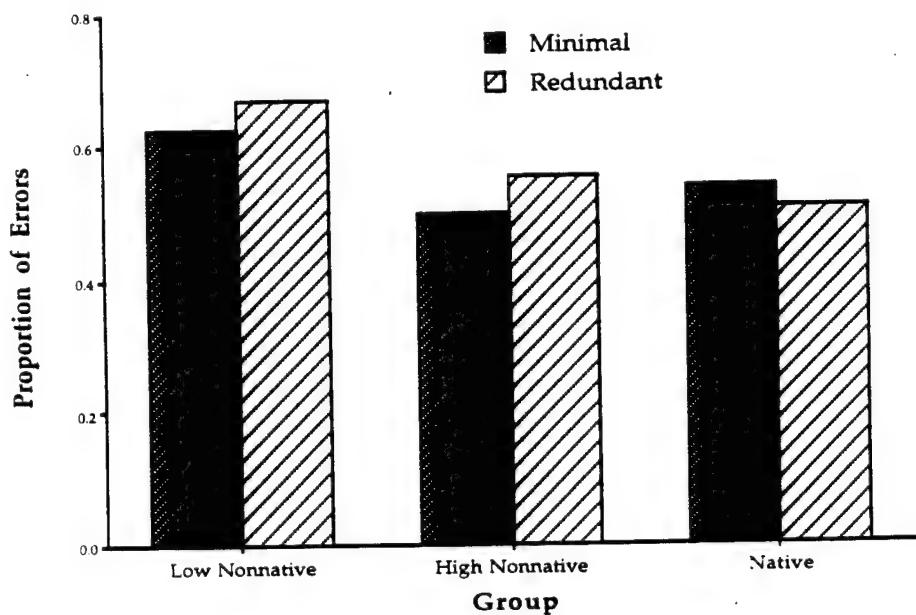


Figure 35. Proportion of errors as a function of message redundancy and fluency level in Experiment 3 of the study involving nonnative speakers of English.

In these experiments with nonnative speakers of English, we have essentially replicated our earlier results. Finding the same pattern of results with nonnative speakers, even those with low fluency, as we do with native speakers of English suggests that our results reflect cognitive processes that are language independent, such as memory processes.

Overall, our findings imply that to insure maximal message comprehensibility, speakers should reduce the number of propositions included in a given utterance but employ a speech rate and a level of redundancy at which they are most comfortable.

#### Memory Skills

Most recently we have initiated studies that extend our previous research by examining training situations beyond those limited to the foreign language domain and by emphasizing the generalizability of what is learned and retained. This new emphasis was prompted by two main outcomes of our earlier studies. First, we found an amazing durability of knowledge and skills in certain domains which we explained in terms of a "procedural reinstatement hypothesis," according to which long-term retention depends on the extent to which test procedures (i.e., operations) reinstate (i.e., repeat) procedures employed during learning (see, e.g., Healy, Fendrich, Crutcher, Wittman, Gesi, Ericsson, & Bourne, 1992). Second, we found that typically the more durable the memory for a certain kind of knowledge or skill, the less generalizable it is beyond the circumstances in which training took place (see, e.g., Healy, King, Clawson, Sinclair, Rickard, Crutcher, Ericsson, & Bourne, 1995). Thus, we were able to identify training conditions that promote durable memory, but we have only now begun to explore ways of promoting the generalizability, or transferability, of those durable memories. This need is particularly crucial to military tasks because training circumstances can rarely capture the full set of circumstances under which these tasks are encountered in the field.

Following this new emphasis, we have begun to investigate ways to promote the generalizability and transfer of memory skills. We started with the message comprehensibility paradigm just summarized, but we simplified that paradigm, removing the linguistic component, to isolate the memory skill component (Marmie, 1996). Specifically, we used a single grid including 64 squares. For the memory task, subjects viewed one square at a time highlighted on this grid. Unlike our study of message comprehensibility, in this memory task the location of the first highlighted square varied across trials, and the location of any subsequent highlighted square did not depend on the location of the previously highlighted square. Also, unlike our study of message comprehensibility, nothing was heard or spoken by the subjects in this memory task; their task was simply to repeat the sequence of highlighted squares by clicking the appropriate squares of the grid with a mouse. But like our study of message comprehensibility, we systematically varied the number of squares in the sequence.

We began with the hypothesis that the best way to promote generalizability of this spatial memory skill would be to practice the memory task under varied, rather than constant, training conditions (see, e.g., Schmidt & Bjork, 1992). This variability of practice hypothesis first emerged in research on the transfer of training of motor skills, but, to our knowledge, it has not previously been investigated for memory skills.

To test the variability of practice hypothesis for memory skills, we compared five different types of practice schedules across subjects in our first experiment. The first three types all involved constant practice scheduling on a single task. Specifically, one group of subjects practiced with sequences of 3 squares in length, a second group with sequences of 4 squares in length, and a third group with sequences of 5 squares in length. The last two types both involved variable practice scheduling on two tasks differing in sequence length. Subjects in both of these groups practiced with

both sequence length 3 and sequence length 5. In the variable blocked group, subjects practiced with a single sequence length in each block of training, whereas in the variable random group, subjects practiced with both sequence lengths mixed randomly in every block of training.

Following 8 blocks of training of 8 trials each, all subjects were given a series of transfer blocks in a counterbalanced order. Each transfer block involved a different sequence length, ranging from 2 to 6 squares. Each transfer condition had several different relationships to the various training conditions. Specifically, the transfer condition could either match or mismatch the training condition, and a mismatch could occur in different ways. First, the transfer condition could occur either within or outside the practiced range. Second, the transfer condition could occur either to a more difficult or to a less difficult task. Our procedural reinstatement hypothesis leads to the prediction that transfer should be optimal given a match between training and transfer conditions, and the variability of practice hypothesis leads to the prediction that transfer should be better for variable training than for constant training and better for variable random training than for variable blocked training.

Although there were no effects of training condition on accuracy in the transfer tests, there were reliable effects of training condition for total response time. As summarized in Figure 36, which shows response time averaged across all five sequence lengths in the transfer test, there is a distinct advantage for the variable random practice condition relative to the other practice conditions, including all three constant practice conditions as well as the variable blocked practice condition. This faster responding for the variable random condition is consistent with the variability of practice hypothesis.

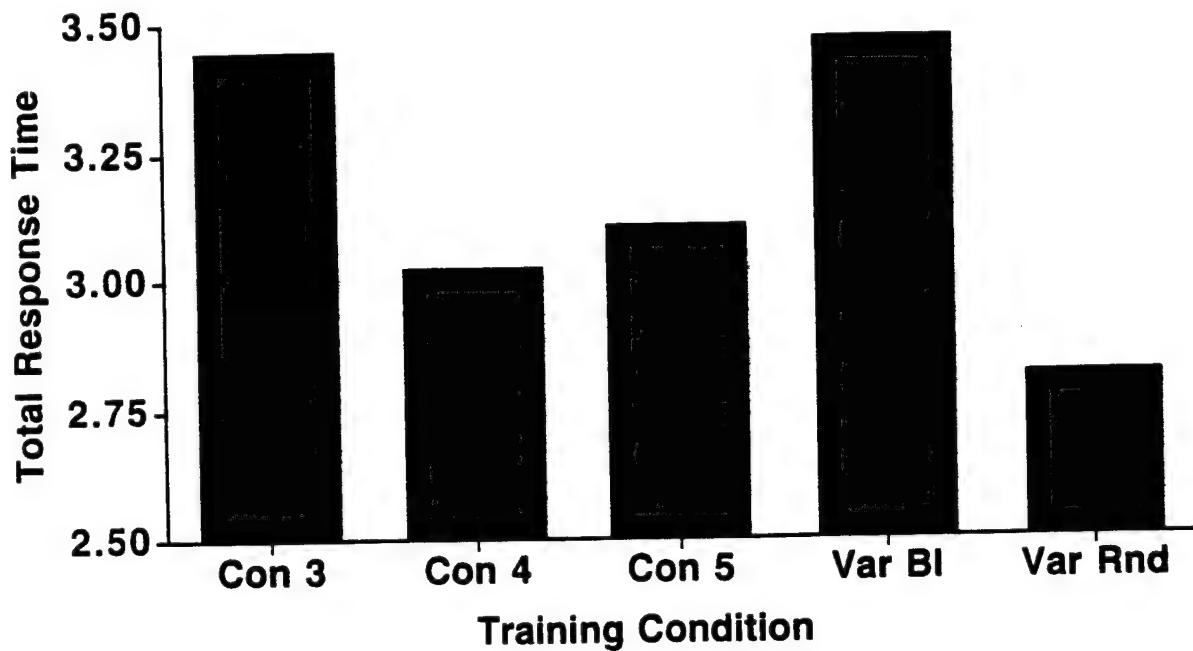


Figure 36. Total response time on the transfer test averaged across all sequence lengths as a function of training condition.

Most interesting with respect to the procedural reinstatement hypothesis, as shown in Figure 37, are the results for transfer trials involving sequence length 3. Subjects in the constant 3 practice condition received twice as

much practice on sequence length 3 as did subjects in the random variable practice condition, so that there was a better match between training and transfer conditions for the constant 3 practice condition than for the random variable practice condition. Nevertheless, for transfer to trials with sequence length 3, the variable random practice condition yielded faster total response times even than the constant 3 practice condition. Hence, variable training seems to be even more important to eventual performance on a task than sheer amount of practice on that specific task.

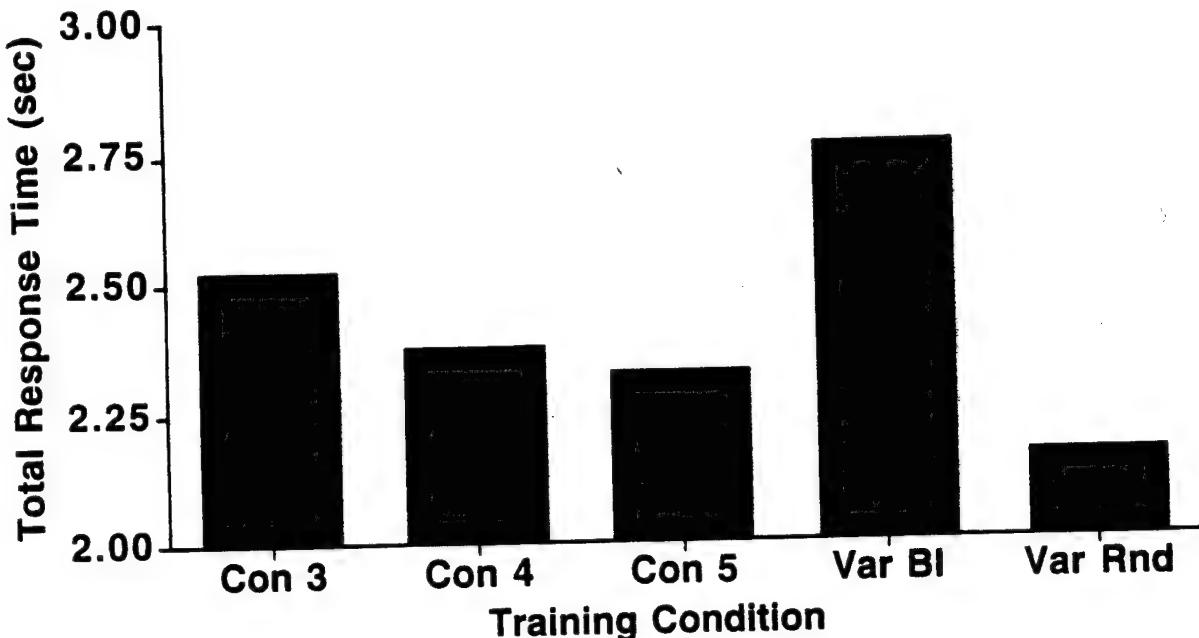


Figure 37. Total response time on the transfer test for Sequence Length 3 only as a function of training condition.

#### Summary

To summarize, we will review the major issues we hoped to address in this research. On each issue, we are now in a position to provide evidence from research we have completed.

First, we asked "To what extent does a person adopt or adapt first-language strategies in the acquisition and use of a second language?" The tentative answer is, "Whenever possible." We found that Chinese and Japanese speakers, whose languages have frequent zero anaphora, but not Dutch speakers, whose language has infrequent zero anaphora, more easily comprehended modified English (that is, second language) discourse containing abundant zero anaphora than did native English speakers, whose language rarely contains zero anaphora. Thus, it is clear that discourse strategies developed to enable reference tracking in one's first language are readily adapted for use in a second language when appropriate.

Second, we asked "What are the basic methods for efficient and durable acquisition of vocabulary items in a foreign language?" We have several answers to this question. First, we found that mediational instructions were superior to less specific instructions and improved both the time required for vocabulary learning and the amount retained. Second, we found that the keyword method is effective for acquisition of vocabulary pairs, and we demonstrated that the accessibility of the keyword from the foreign word

increases its effectiveness and that the conceptual aspects of the keyword remain important mediators even well after mastery of the vocabulary pairs. Third, we found that the pronounceability of a foreign word in terms of the phonetic rules of one's native language affected the ease of learning the meaning of that word. Thus, it seems best when teaching foreign language vocabulary to use specific mediational instructions and to be sensitive to first-language word pronounceability.

Third, we asked "What role do abstract linguistic categories play in the acquisition of language skill and the day-to-day use of language for the purpose of communication?" We have several answers to this question as well. First, we found that even well-defined linguistic rules are not always known to native speakers. Subjects' behavior was found to be systematic at a lower level of abstraction than that given by prescriptive linguistic principles. Hence, it seems best when teaching a foreign language to avoid exclusive reliance on rules or abstract characterizations but rather to make abundant reference to examples or specific allowable word combinations. Second, we found that individuals made use of both rule-based and instance-based strategies in both natural and artificial linguistic category learning tasks. However, with training, the instance-based strategy came to dominate in the artificial task, whereas the rule based strategy came to dominate in the natural task. Hence, abstract (that is rule-defined) categories played an even larger role in the natural language task than in the comparable artificial task. Despite this difference in dominant strategy, subjects used the rule primarily to categorize novel instances in both tasks. Thus, we conclude that subjects learned something about both the operative rule and the instances presented during training, and they were able to switch strategies appropriately as the task demanded. Our findings suggest that individuals can abstract usable rules from training on small subsets of instances and, therefore, that explicit instructions about rules may not be required in foreign language training.

Fourth, we asked "What are the functional units of any language and how do they differ for the native and nonnative speaker?" We found that the functional units used for reading a foreign language are not transferred from the first language but instead depend on both the speaker's fluency in the second language and the orthographic relation between the two languages. Hence, when teaching a foreign language it seems best to refer to functional units appropriate both in light of the student's level of knowledge and the orthographic similarity between the student's first and second languages. In our investigation of the units used in a memory representation of a text, we also discovered that individuals have control over the memory representation they use to store a text and the chosen representation affects what they can retrieve from memory. Consequently, to maximize memory retrieval, students should be encouraged to use multiple forms of memory representation.

Fifth, we asked, "How do knowledge of the language and utterance complexity interact to determine message comprehensibility for a listener?" We have results showing that the number of propositions in a given utterance plays a large role in determining message comprehensibility, that speed of pronouncing the utterance and message redundancy play minimal roles, and that practice modulates these effects. We have found that these results hold for nonnative speakers of English as well as for native speakers. These results imply that to insure maximal message comprehensibility, speakers should include no more than three propositions in a given utterance but employ a speech rate and a level of redundancy at which they are most comfortable. In our investigation of training conditions that optimize generalizability, we have found support for the variability of practice hypothesis in the transfer of a memory skill. In fact, it seems that variable training is even more important to eventual performance than sheer amount of practice. Although this study used a spatial memory task with no linguistic input, the findings

imply that in foreign language training as well, the scheduling of practice may be an even more important variable than the amount of practice in determining overall performance levels.

We have been able to resolve some of the issues we raised, and we have reached some important conclusions concerning foreign language training. Nevertheless, there remain many related issues concerning the development of psychological principles that would provide the foundation for a foreign language training course. But we trust that we have made sufficient progress to consider the next important step, which would be to adapt and apply the principles we have summarized above in an actual training environment. We encourage future efforts in this direction.

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Payne, D.L., & Barshi, I. (1995, July). A wholistic approach to possessor raising in Maasai: Speaker's motivation, language constraints, and

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Proctor, J.D., & Healy, A.F. (1994, November). Specificity and durability of practice effects for letter detection in prose. Poster presented at the 35th Annual Meeting of the Psychonomic Society, St. Louis, MO.

Rickard, T. (1995, November). Bending the power law: The transition from algorithm to retrieval. Poster presented at the 36th Annual Meeting of the Psychonomic Society, Los Angeles, California.

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Schmalhofer, F., Aitken, J.S., & Bourne, L.E., Jr. (1994, January). Beyond the knowledge level: Descriptions of rational behavior for sharing and reuse. Paper presented at the Knowledge Acquisition workshop, Banff, Alberta, Canada.

Smith, R.W., & Healy, A.F. (1996, July). Time-course of the generation effect. Paper presented at the eighth Annual Convention of the American Psychological Society, San Francisco, California.

Tao, L. (1993, October). Zero anaphora in Mandarin Chinese discourse. Paper presented at the 28th Annual Mid-America Linguistics Conference, Boulder, Colorado.

Tao, L. (1994, May). Topic discontinuity and zero anaphora in Mandarin Chinese: Cognitive strategies in discourse processing. Paper presented at the biannual Charles Li Anaphora Symposium, Allenspark, Colorado.

Tao, L. (1994, July). Topic choice, switch reference and zero anaphora: The on-line construction of grammar. Paper presented at the Fourth International Symposium on Chinese Linguistics and Typology, Taipei, Taiwan.

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Tao, L., & Healy, A.F. (1995, July). Information flow and zero anaphor: A comparison of native English and native Chinese speakers. Paper presented at the International Conference on Functional Approaches to Grammar, Albuquerque, New Mexico.

Tao, L., & Healy, A.F. (1996, November). Transfer of reference tracking strategies from Chinese to English. Paper to be presented at the 37th Annual Meeting of the Psychonomic Society, Chicago, Illinois.

Tao, L., Healy, A.F., & Bourne, L.E., Jr. (1995, April). Unitization effects in the process of second-language learning. Paper presented at the Sixty-fifth Annual Convention of the Rocky Mountain Psychological Association, Boulder, Colorado.

Tao, L., Healy, A.F., & Bourne, L.E., Jr. (1995, November). Unitization in second-language learning: Evidence from letter detection. Poster presented at the 36th Annual Meeting of the Psychonomic Society, Los Angeles, California.